A GUIDE TO THE ASEPTIC TREATMENT OF WOUNDS

BY

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PREFACE BY

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TRANSLATOR'S PREFACE.

It was with the belief that a service of some value might be rendered to the American profession, including practitioners and students, that I have undertaken the translation of this work. The flattering reception given to the first and second editions in Germany, and the fact of the very early translation of the former into several foreign languages, justified the inference that this might prove a timely and serviceable contribution to English medical literature.

The improved knowledge of micro-organisms and of their influence in the causation of the transmissible wound diseases has so completely revolutionized surgical ideas, and led to such extensive alterations in surgical methods, that a demand seems to have been created for a concise treatise which would embrace the advances made and plainly indicate the present relations of the results of bacteriological study to surgery.

To practitioners who have not had the opportunity of observing the character of work done in the modern operating arena, a manual of this kind must be of particular value. The simplest surgical procedure—a catheterization, the administration of a hypodermic injection, or the dressing of even the slightest wound—requires for the insurance of its successful issue and the avoidance of danger, an accurate understanding of the principles of asepsis ; in the performance of all major operations such knowledge is imperative.

The student will, through the medium of this volume, be enabled to acquire a more comprehensive view of the application of the most recent bacteriological researches to surgery than his general teaching will ordinarily admit ; while the skilled operator is presented with a digest of the literature pertaining

to asepsis, and a summary of the methods which the present status of the subject shows to be indicated in the preparation for all operative procedures.

I have added some notes and seven illustrations which it is hoped may tend to enhance the efficiency of the manual. If the latter serves to disseminate the knowledge upon which a continuance of the strides in surgery must primarily be based, I will feel repaid for my efforts in presenting the work to the profession.

FRANK J. THORNBURY.

469 Delaware Avenue,
Buffalo, New York.
May 1, 1895.

PROFESSOR VON BERGMANN'S PREFACE.

DURING the Tenth International Medical Congress the undersigned had exhibited in a pavilion of the clinic, erected for that purpose, the implements for the sterilization of dressings and assigned to his assistant, Dr. Schimmelbusch, the work of demonstrating their efficiency upon those micro-organisms which come into question in connection with wounds and wound treatment. The coloration which the bacillus of blue pus produces in its growth enabled the visitor to the exhibition to convince himself, without the microscope, of the efficient working of the methods presented.

From all sides we were then requested to formulate and publish the work which our exhibit represented.

This request it shall be the purpose of the book laid before you to fulfil. What I, with my former and present assistants, Professor von Bramann, Privatdocent Dr. Schlange, Dr. de Ruyter, and especially Dr. Schimmelbusch, have now and then in lectures and dissertations publicly contributed, is not only here again taken up but is elaborated into a text-book of the *Aseptic Methods of Wound Treatment* by him who for years has been pre-eminently active as assistant in my clinic.

However great and revolutionizing in the science of surgery the transition of antisepsis into asepsis has become, there has still been wanting a uniform presentation of the latter.

What Nussbaum's guide-book afforded antisepsis, there has

been lacking in asepsis. To supply this want the publishers have contributed in that they have provided us abundantly with old and new illustrations. It affords us pleasure in this connection to be permitted to express our thanks to the venerable and untiring Mr. Ed. Aber.

I have myself almost daily felt in my clinical demonstrations that my instruction in aseptic wound treatment was too brief and inadequate to the requirements of the student.

The clinic time is completely absorbed by the extensive and important material, consequently our hearers require a compend and a text-book which they can subsequently read and from which they can provide themselves with an understanding of the work that is presented in the clinic. This want, it has been the aim of Dr. Schimmelbusch in his book to fulfil. May it be of value to the student as well as to the practising surgeon.

ERNST VON BERGMANN.

AUTHOR'S PREFACE.

THE American edition of my *Aseptic Wound Treatment* I greet with particular pleasure, especially as it is intended to present the product of many years' work in the von Bergmann clinic, to appear now in its second revised edition before the forum of the reputed foreign medical profession. May the little volume be received as kindly in America as it has been in Germany, and may the profession on the other side of the ocean gain the impression that the author has always been guided by earnest endeavor and the best intention.

It is especially gratifying to me that I have been able to intrust the translation of my book to so competent a physician as Dr. Thornbury. I could desire no better interpreter—one who is surgeon and at the same time bacteriologist, and who by reason of his long presence in the von Bergmann clinic has acquired an exact personal knowledge of the methods of which the book treats.

DR. SCHIMMELBUSCH.

CONTENTS.

LIST OF ILLUSTRATIONS.

A GUIDE TO THE ASEPTIC TREATMENT OF WOUNDS.

A GUIDE TO ASEPTIC WOUND TREATMENT.

CHAPTER I.

THE IMPORTANCE OF ASEPTIC WOUND TREATMENT.

Uncertainty of the Former Results in Operations—Certainty of the Present as Regards Wound Repair—The Short Duration of Repair—We no longer Fear a Special Diathesis in Wound Inflammation, nor the Age of the Patient—We Open the Abdomen and Cranium without Hesitation—Knowledge of the Agents of Wound Infection—Lister.

It is appropriate for one who is reaping the benefits of great achievements, and taking them as a matter of course, and who, notwithstanding, may have doubts as to the practical good of new methods, to review the past and contrast it with the present. It will not be necessary to go back to the period in which the want of anatomical and physiological knowledge, as well as imperfection in technique, restricted the accomplishments of surgery; the time does not extend over more than three or four transpired decades. He compares with the new era only such departments of our science as were common to our most progressive representatives with whom advances in the methods of operating reached so high a standard as to leave but little remaining to be done, but all of which was vitiated and all results placed in question through a mysterious and incomprehensible destiny which hovered over the injured

and those operated upon. This was the time in which wounds and fevers were regarded as inseparable, when healing without inflammation was unknown, and wound fever and inflammation appeared as the natural reaction of the injured organism.

It was then that Pirogoff wrote his dissertation upon *Fortune in Surgery*, in which, after years of experience, he became so resigned to the feeling of powerlessness in his own art that he made the peculiarly adaptable announcement : "that the influence of the physician, the therapeutic resources, and mechanical dexterity are of no importance ; the results of an operation are dependent entirely upon chance." The scourges of surgery — as aptly styled by Pirogoff,— suppuration, purulent œdema, hospital gangrene, erysipelas, and tetanus, followed the surgeon step and pace, thwarting all his efforts.

"Eighty per cent. of all wounds are attacked with hospital gangrene," wrote Lindpainter from Nussbaum's Clinic in Munich. "Erysipelas was so frequent with us that we might have regarded it as almost an expected occurrence. We made it a standing rule not to suture any scalp wound, as union by primary intention was practically never observed : and suturing had at most the effect of favoring the development of erysipelas by causing retention of the secretions. Out of seventeen cases of amputation in one year, eleven died of pyæmia alone. A complicated fracture in our department was seldom seen which, if not amputated immediately, was not attacked in a few days by purulent infection, hospital gangrene, or septicæmia, which led to rapidly fatal termination."

The mortality in complicated fractures in Volkmann's Clinic at Halle, in the many years' experience of his predecessors, as well as during his own practice, amounted to fully 40 per cent. and in the years 1871 and 1872, the number of victims claimed by pyæmia and erysipelas became so great that Volkmann conceived the idea of closing his department for a time.

How different is the whole aspect to-day! The hospitals which twenty years ago numbered gangrene among the most frequent of their wound complications now never present a case for the observation of the student, and the majority of younger physicians are not acquainted with this disease. Operations performed by the modern surgeon run a course with so favorable a certainty that the thought of a mishap in the repair is scarcely ever entertained. Death as a result of wound inflammation after an amputation is no longer an inevitable consequence. There is no "fortune" and "misfortune" now in surgical treatment, but instead, the fate of the patient rests in the hands of him who performed the operation and dressed the wound. The old saying of Ambroise Paré, "Je le pansais, Dieu le guerit," has ceased to be the unwilling confession at defence for the operating surgeon, and he who now dresses a wound assumes the whole responsibility and is answerable for perfect and certain union. "Until very recently," said Volkmann in his admirable manner of expression, "the surgeon in performing a sanguineous operation was like unto the farmer, who, when he has planted his fields, awaits the result of the harvest and reaps it as it may chance to come, powerless to exert any influence over the mighty elements which may bring him rain, storm, winds, or hail." To-day he is like the manufacturer from whom we await good products.

The duration of the wound repair in modern surgery is completely changed. In the year 1875, Nussbaum complained that injured persons of the lower classes were limited to a nine-weeks' course of treatment by the hospital regulations, and contended that for many this time was insufficient, and that even in unimportant wounds, by reason of inflammation, the healing process was not completed until after a much longer time. Union after an amputation of the mamma then required one fourth to one half a year; healing of large

amputations often occupied months. We now observe complete recovery after removal of the breast, with extirpation of the contents of the axillary space, in fourteen days; and in cases of amputation of the thigh, we deplore having to retain the patient in the hospital over the third week, if we have had the case for arrangement of the prothesis.

Our whole conception and understanding have been essentially altered. We no longer believe that in a carcinomatous or tubercular individual a fresh wound must heal otherwise than in a healthy person; the phantom of a diathesis predisposing to inflammation has vanished. We operate with the same assurance of a favorable result in the infant and in the aged as in the most robust man. The modern surgeon no longer anxiously avoids the injuries to joints and visceral cavities, but opens the abdomen and the cranium without hesitation, and palpates organs which were a *noli me tangere* to the ancients.

For this enormous transition in surgical science we are alone indebted to the great discovery which, with one impulse, illuminated the mysterious darkness that for centuries hovered over wound infection; which taught us that putrefaction, fermentation, as well as infection, are dependent upon the minutest material forms of life, and that all that is necessary to the avoidance of infection is their exclusion.

Even though the weapons which we now employ in combating the recognized enemy are different from those which were first chosen, and although later times may bring newer and better methods, we will always be indebted to him who first showed us the way in which we are advancing, and there will always appear before us in most brilliant light the name of Sir Joseph Lister.

CHAPTER II.

AIR AND CONTACT INFECTION.

The Belief in the Transmission of Disease through the Air is very Ancient—Sir Joseph Lister's Teaching—Subcutaneous Operations—Lister's Methods were Originally Directed against Air Infection—Later Investigations Regarding the Bacteria Contained in the Air—It is not the Air but rather the Organic Material of the Earth's Surface which is the Natural Habitat of Micro-Organisms—Only as Dry Dust do Germs Gain Entrance to the Atmosphere—From Moist Surfaces they cannot Arise—The Breath of Man is always Free from Bacteria—The Number of Bacteria Present in the Air is markedly Less than in Organic Material—In the Air only Few Pathogenic Organisms are Found—Infection from this Source is consequently Less to be Feared than Contact Infection—Practical Experience has Demonstrated the Harmless Effect of Air Free from Dust when it Encounters Wounds—It is not Necessary that we should Adopt any Special Prophylactic Measures against Air Infection if we only Avoid the Stirring up of Heavy Clouds of Dust—Contact Infection Merits the most Particular Attention.

More ancient than medical science itself is the belief in the transmission of the elements of disease through the air. In surgery the opinion was long prevalent that wound infection was dependent upon an atmospheric influence, and this view became dogmatic after John Hunter attributed the invariable absence of fever and suppuration in subcutaneous injuries, such as simple fractures, to the fact of their not having been reached by the air. When formerly cases in a hospital developed fever and suppuration, it was the contaminated air of the wards which the surgeon regarded as the source of all evil. The whole aim of surgery in the recommendation of the so-called subcutaneous method of operating, introducing the

instruments through the smallest slit-like opening to divide, in a groping way, deep in the tissues, tendons, and saw through bone, is in accordance with the endeavor to imitate the character of subcutaneous injuries and procure wounds to which the air has no entrance. Against nothing else than the air itself did Lister direct his first endeavors at asepsis, not against the air as a gas, however, but rather against the elements of decomposition contained in the air, which he supposed induced these changes in the wound secretions and in the wound itself, as they produce changes and decomposition everywhere in organic material. Thus began Lister in his first communication in the *Lancet*, 1867, regarding a new method of treating compound fractures and abscesses: "The almost invariable absence of danger in simple fractures stands in striking contrast to the disastrous results which we otherwise often have occasion to observe, and the excessive frequency of which is one of the most striking and grave incidences of surgical practice. Investigating the actual reason why the wound in a compound fracture may prove so disastrous, we find simply as explanatory the septic changes in the blood which is poured out in greater or less quantity about the seat of fracture and into the connective-tissue spaces, such changes being induced by the entrance of air, and the blood losing its mild character to take on the quality of an active irritant, and produce local and constitutional disturbance."

The investigations of Pasteur, Schwann, von Dusch, and others, taught us that organic material, blood and tissues, may be preserved from decomposition by protecting them from contact of the minutest living organisms, and so Lister in his new method endeavored to exclude from the wound the germs of decomposition. He irrigates the latter with carbolic acid (with the use of which in counteracting decomposition he had had a remarkable experience in deodorizing the fields over

which the contents of sewers were allowed to flow slowly and settle outside of the city of Carlisle), in order to destroy the germs which the air had already carried into the wound. He then applied the dressings, which were saturated with carbolic acid, and with the greatest possible care bandaged in the entire wound, making the occlusion complete by using a layer of impermeable material so that entrance of germs from the air was precluded. During the operation and at the subsequent change of dressing, the carbolized spray in addition was disseminated over the entire region of the wound, this being intended to place the injured area in an atmosphere which would be entirely free from dangerous organisms of every variety.

At the time when Lister made the first practical trial of his new method of treatment, our knowledge of the germs contained in the air was very limited. That they existed as the minutest forms of living matter had, it is true, been recognized, but regarding their extent, morphological characteristics and appearance, and their requirements for existence, almost nothing was known. Tyndall had shown that they appertain to the sunbeams which become visible when the rays of light fall into a dark room through a crack in the closed window shutter; it is also a fact that Pasteur aspirated air through gun-cotton, and filtered out the germs, then dissolved the gun-cotton in ether and examined it microscopically, and that Pouchet collected particles of dust on moist plates against which air was blown, but all these investigations have availed us but very little. The fact that in a comparatively short time we have attained a quite thorough and more or less complete understanding of the extent, size, form, appearance, and manner of life of the air bacteria, is the result of nothing more than the brilliantly perfected methods of bacteriological investigation for which our tribute of gratitude is due pre-eminently to Robert Koch.

If we review the results of our most recent investigations into the bacteria of the air, we find throughout a conformity to exist, and this concordance has the greater significance in view of the varying methods of investigation employed by different observers.

Practically all forms of germ life, which we comprise under the common name micro-organisms, are found in the air, and have a widely varying distribution ; bacilli, cocci, yeast fungi, and hyphomycetes are usually all present at the same time. As well in the extent of their dissemination as in their number are there extreme variations, but these differences have a decidedly peculiar relationship, and are always dependent upon corresponding circumstances. For instance, in dwelling-houses bacteria, bacilli, and cocci predominate over the mould fungi, while in the open atmosphere more mould spores are present. The number of germs varies from a few, to many thousands per cubic centimetre. The air of large cities contains greater numbers of bacteria than does country air ; in damp weather the number of bacteria in general is less than in dry weather ; in winds greater numbers are present than in still air ; in the middle of the Atlantic Ocean and upon mountains in the Alps range which are continually covered with snow, the air is practically free from bacteria. This fact of the absence of organisms in sea atmosphere the translator recently substantiated in a transatlantic voyage. Land winds usually contain more bacteria than do sea winds ; for instance, the wind which blew from the land towards Catania, as found by Condorelli-Mangeri, always revealed more germs than the wind which blew from mid-sea toward Catania. The same conditions with reference to sea and land winds were confirmed by Uffelmann in Rostock and Giorgio Roster on the island of Elba.

Many of the older writers, for instance Loewenhoek, main-

tained that all bacteria originate from the air, and that from this source organic material is infected and its decomposition induced. This same line of thought was also very evident in Lister's first writings. The opinion that the air is the natural habitat of the micro-organisms, and that from this source organic material is infected secondarily, we must, with our present knowledge of the requirements of the bacteria for existence, positively contradict. It is not the air which *par excellence* broods and harbors the deadly organisms and acts as the source of infection of everything else ; the conditions are rather the reverse ; it is in organic material that the germs exist, and only exceptionally do they from that gain entrance to the air. All the requirements for growth and multiplication of micro-organisms—warmth, moisture, and a nutrient media—are not present in the air, and for the schizomycetes, yeast fungi, and mould spores, the air is anything but a favorable place of maintenance.

Then there are bacteria, the so-called anærobic organisms, which are antagonized in their growth by the air as a gas media—among this class we have the bacillus of tetanus ; and there are present in the air, especially in a clear atmosphere, a number of factors, such as dryness, diffuse daylight and sunshine, which exert an unfavorable or directly damaging and destructive influence upon the low organisms.

Only transitorily do micro-organisms gain entrance to the air from their essential habitat—the warm, moist, and organic material of the earth's surface ; and then under only one condition, viz. : when they are disseminated as dry dust in breezes. Naegeli as early as the year 1870 showed theoretically and experimentally that only as dry dust can micro-organisms become mixed with the air, and that never do they gain entrance to the latter from fluids containing them. And yet even to-day it is difficult for an individual who inhales the

nauseous vapors of decomposing fluids to reconcile himself to the belief that with the fumes germs are not disseminated, notwithstanding that all the investigations made in this direction have proven the incorrectness of this opinion. Air offensive in odor frequently contains fewer bacteria than that which we inhale as pure and agreeable, and the stinking atmosphere of out-houses, sink-holes, and sewers has always been found purer bacteriologically than the air of streets, dwellings, and gardens.

According to investigations made by Hesse and Petri the open air in the interior of Berlin always contains from several hundred to over 1000 bacteria per cubic metre, that of dwelling-houses from 6000 to 10,000, while Petri alone found that the air in the canal below Potzdamer Place showed none at all or only a few scattered germs. In fact, the air under Potzdamer Place is bacteriologically the purest in the whole city of Berlin, and even at the top of the Court House tower an individual would inhale a greater number of germs, as there, according to Hesse, 800 bacteria per cubic metre are present. It has been experimentally proven that even through powerful currents of air passed over the upper surface of fluids containing bacteria, germs are not disseminated; the solution only is stirred up and then settles, carrying down with it the bacteria.

The sun which pours its hot rays upon stagnant pools swarming in micro-organisms, vaporizes the water and generates foul odors, but never are bacteria liberated, and even though the drops of rain, and hailstones the size of a walnut, which were showered over St. Petersburgh in a storm, revealed bacteria (Foutin), we are not to infer that these germs arose from the water as it evaporated. The dust particles in the atmosphere became enveloped in the precipitation.

The presence of greater numbers of bacteria in dry and moving, than in moist air, is a sequence of the extensive circu-

lation of dust which is induced by dryness. The reason why there are fewer bacteria in the air after, than before a rain, is because the water in falling carries down with it the germs, and the saturation of the earth's surface, caused by a protracted rain, prevents temporarily the raising of dust. The absence of micro-organisms in the air upon icebergs and in mid-ocean, is due simply to the fact that there is no dust containing bacteria which can be stirred up by the motion of the air, and that the glaciers as well as the sea-water hold down the bacteria contained in them.

Condorelli-Mangeri found, in Catania, that during the great assemblages of the multitudes at the time of earthquakes, the air contains more bacteria than at other times. The air of stalls in which small animals are kept and move about, as, for instance, in the pens of the Hygienic Institute, Berlin, is, according to Petri, very rich in germs; it contains upwards of 34,000 bacteria and about 7400 mould fungi per cubic metre. In the air of workshops the number of bacteria increases rapidly as soon as the work is begun, and in barracks, hospitals, and dwellings the germs are always most numerous shortly after the rooms have been swept and dusted.

In the operating room of the Billroth Clinic, the number of bacteria in the air is greatest while the clinic is in progress, after the students have entered, and according to Hess the germs in the air of a school-room increase from 3000 per cubic metre to 20,000 during the sessions, and to 40,000 during the exit of the pupils. Analysis in the von Bergmann Clinic made at various times during the day showed that the germs in the air were always most numerous directly after the wards were cleansed in the morning, while during the night they gradually diminished (the author and Cleres-Symmes). All these observations only illustrate further the effect of the stirring up of dust upon the bacteria contained in the air.

Very general in medicine as well as among the laity is the belief in the infectiousness of the breath, and this sentiment finds vivid expression in the fictitious narratives of very ancient times, which attributed to a vigorous exhalation of the monsters the propensity of destroying everything it encountered. It is surprising that at the beginning of the antiseptic era special importance was not ascribed by surgeons to the expired air as a source of wound infection, for it is not difficult to understand, *a priori*, that from the views in vogue a variety of opinions might have been formed.

Exact bacteriological study has, however, dispersed these views, and even though the air of an overcrowded room rapidly deteriorates and becomes irrespirable, it is to be emphasized that germs, comprising the bacilli and mould fungi, do not participate to any appreciable extent in this deterioration, and that the latter, as in sewers, pertains more especially to the gaseous constituents.

Since Tyndall discovered that the breath of man is entirely free from bacteria, a variety of investigations of the exhaled air have been made, and concordantly they have shown that micro-organisms instead of being given off from the respiratory tract are rather taken up from the air and filtered out.

Of 600 germs inhaled from the air of sick-rooms very rich in bacteria, not more than one is found in the exhalation according to Strauss. Cadéac and Malet placed healthy sheep opposite to animals affected with anthrax and sheep pox, and allowed them to breathe for long intervals through tubes 0.30 to 1.50 metres in length, varying their experiments in a number of ways, but never were they successful in infecting, through the breath of diseased animals, those which were healthy. As intimated the lungs do not give up bacteria from their moist alveolar surfaces, but rather have an opposite effect, working as filters, and only is it possible for the expired air to

act in the transmission of germs when sputum, mucous secretion or tissue shreds are expelled from the respiratory tract in paroxysms of coughing.

As correctly stated by Strauss, the bacteria contained in the air of an overcrowded apartment must be diminished by the act of respiration, and it may be of consolation to a clinical lecturer, whose auditorium becomes filled with listeners, entering in the raising of dust, to know that each individual brings with him in the capacity of his lungs a filtering apparatus, and that with each act of respiration he renders about 500 cubic centimetres of air free from bacteria. The surgeon need not fear that he will infect a wound with his breath, nor that a patient suffering from sepsis can fill the air of a ward with infectious bacteria in the act of respiration.

The more our bacteriological knowledge has been extended, the more frequently the true source of bacteria has been investigated, and the more we have endeavored experimentally to transmit the wound diseases, so much the more has our fear of an infection through the air diminished, and so much the less appears to be the danger of disease being communicated in this way as compared with the direct contact of infectious materials.

The simple consideration of the number of bacteria which can gain access to a wound through the air, as compared with contact, is sufficient to reduce our fears of the so-called air infection. The thought of a cubic metre of air containing 1000 or indeed 20,000 or 40,000 germs, is naturally striking, but what are these numbers compared to the bacteria contained in decomposed organic materials! The Spree River water in Berlin, for instance, presents in each cubic centimetre —*i. e.*, in the millionth part of the above quantity of air—as many thousand bacteria, and the number of germs in a drop of pus or other heavily decomposed fluid amounts to millions.

Let us take to illustrate these relations a frequent instance in practice.

The germs of the atmosphere which gain access to a wound settle upon it from the air moderately in motion, in accordance with the laws of gravity. By repeated investigations in the von Bergmann Clinic we have proved that in the operating room with auditorium occupied, the number of bacteria which settle upon the surface of a wound a square decimetre in extent, in the course of a half hour, is about 60 to 70; the number which deposit from the open air in the vicinity of the clinic being, however, much less. The Spree River flows just past the clinic, and the bacteria which it here contains, according to investigations in the Hygienic Institute, varies from 3200 to 150,000 per cubic centimetre, the average number being 37,525. Let us consider, now, the not infrequent instance of a ship-hand upon the Spree receiving a wound—and suppose it happens to be a wound a square decimetre in extent—the individual coming to the clinic with the wound open and undisturbed, although exposed to the action of the air, would receive upon its surface, in the lapse of one half an hour before application of the dressing, at most from 60 to 70 germs, which are scattered only loosely and very superficially over the blood-clots. If, in accordance with the usual custom, the wound be now irrigated slowly and thoroughly with a litre of Spree water, for the purpose of "cleansing," we may readily estimate that over 37 million micro-organisms are brought in contact with it, and all efforts at numerical calculation are defeated when, in addition, the part is wrapped in a dirty cloth to which is usually adherent masses of decomposed material rich in bacteria.

Lister was of the opinion that the bacteria of the air which produce changes and decomposition in organic substrata are also those which cause wound infection. Modern investigation has long since demonstrated the incorrectness of this

opinion, however, and shown that the germs of wound infection are entirely different from those of ordinary putrefaction scattered over the earth.

The direct examination of the air for the now recognized causes of wound infection in man has afforded very scant and, for the most part, negative evidence.

By far the greater number of air fungi belong to the innocent germs, including the mould spores, yeast plants, and some bacteria which for man are not pathogenic.

When the germs of wound infection have been found in the air, as in hospitals, they have, as compared with other micro-organisms, been greatly in the minority, and we learn, as the result of all our investigations, that the air which is inherently an unfavorable abode for organisms, allows the bacteria of wound infection which unavoidably gain access to it, to die very suddenly.

Thus gradually the theories in vogue have been forced to decline, successively, as accurate investigation has progressed; and of the original views of Lister regarding the importance of the bacteria of the air in wound infection, almost nothing remains. In practice, however, Lister's original views experienced what frequently happens to those put to practical test. Uninfluenced by the manner and complexity with which the method was presented as an established requirement, the good qualities and truth have crystallized out, and the non-essential and superfluous have been abandoned. Thus prior to the evidence afforded through experimental bacteriology, the importance of air infection to the physician had gradually diminished, and from year to year increased stress was laid upon contact infection in the avoidance of wound complications. With timidity first one operator and then another omitted the use of the spray, and finally it rapidly disappeared everywhere, because experience very clearly demonstrated its dispensability.

Similar will be the fate of irrigation recommended by Lister

for the destruction of infectious germs which unavoidably gain entrance to the wound through the air, and which, after discontinuance of the spray by numerous operators, was emphasized as a substitute for the latter.

The results in wound repair which von Bergmann has had for years in his clinic without irrigation, and those which have been attained in the same manner by others who have imitated his example, evidence that the antiseptic wound irrigation does not belong to the true character of modern teaching and is therefore unnecessary. It is not essential that we should have the atmosphere of rooms charged with carbolic acid vapor, nor filter the air which enters through ventilators. It is also unnecessary to deluge our fresh operation wounds with antiseptic agents; we attain favorable results without all these.

The operating room of the von Bergmann Clinic is a polygonal building enclosing an amphitheatre constructed of wood, which at each clinic hour is filled with several hundred students. Large curtains suspended from the ceiling shut off the light on one side; a profuse arabesque lattice-work covers a portion of the rear wall of the room, and just over the heads of the operators, upon *ornamental socle*, are placed the busts of von Bergmann's three celebrated predecessors. No one would suppose that in this room the conditions would be especially antagonistic to the aggregation of dust, and repeated examinations have shown us that the air contains more bacteria than that of any other room in the clinic, but notwithstanding, operations performed here are attended with as favorable results as could be desired.

In this air the abdominal cavity is quietly opened and major amputations performed, pauses are made during the operations, the wound openly demonstrated to the students, then simply sutured, and in no instance, has damage resulted from too long exposure to the atmosphere.

The individual precaution which we are required to observe against infection through the air is in the avoidance of the excessive clouding of dust. We would not be justified in operating where quantities of dust and dirt are blowing about and can encounter the region of the operation. This requirement in the operating room is very easily conformed to and affords difficulty only in the open air. It is well not to clean a room nor sweep just before a major operation, as we have seen that in this way dust always becomes agitated. Further to be observed is special precaution in the disposition of dressings saturated with pus.

That the spray does not exert the favorable influence over the bacteria contained in the air, attributed to it by Lister, is conclusively demonstrated. According to the investigations of Stern, the purifying action possessed by the spray is very unimportant.

So also is it impossible by the ordinary ventilation and airing of a room to effectually diminish the bacteria which it contains.

Stern has showed that after artificial dissemination micro-organisms, which are heavier, gravitate to the surface in the course of one half hour, and the air becomes germ pure. Wool, rag dust, and mould spores require a somewhat longer time for their precipitation.

The most effectual means of freeing the air of a room of its bacteria is to keep the room closed for a number of hours, or until the germs have settled to the floor. Then we have done all that we are required to do in the avoidance of a possible contamination of wounds by this source ; all our further efforts are to be addressed to contact infection.

CHAPTER III.

THE GERMS OF WOUND INFECTION.

The Wound Diseases are Local Disturbances—The Normal Body in State of Health does not Contain Any Bacteria—Germs Gain Access to the Wound from Without—Simple Fractures—Erysipelas, its Cause and Mode of Occurrence—Tetanus—The Pus-Formers and Other Pathogenic Organisms—No Continued Suppuration without Micro-Organisms—The Subject of Wound Infection is not Clear in Every Particular—The Exclusion of Infectious Organisms Remains the Chief Task.

Until comparatively recently true knowledge and proper advancement in surgery were retarded by the generalized impression that many wound infections are not local processes confined to the wound, but rather external manifestations of a constitutional disease, and often only to be interpreted as emanating from a depraved organism. Were it not for the discovery of infectious bacteria, a long time would have elapsed, and much discussion pro and con would been engaged in before this dogma would have vanished. It was only the cloaking of an old doctrine in a new garment when surgeons ceased to question the influence of bacteria in wound infection, but accepted that micro-organisms are present at all times in the apparently normal body, circulating in the blood, and that the injury or wound proper simply affords an opportunity favorable for the development of bacteria. This opinion was the outcome of erroneous calculation, being dependent, in the instances when former investigators believed that they saw with their microscopes—germs everywhere in the tissues—upon the confounding of them with the disintegrated

cell nuclei and other forms of granular detritus. To-day with our improved method of bacteriological investigation it is a very easy matter to take blood and tissue particles from the body and preserve them from decomposition continuously, by observance of proper precautions, substantiating accordingly the absence of micro-organisms in the tissues. But long before this time from the course of subcutaneous injuries,surgeons should have become convinced of the absence of pathogenic organisms in the normal body.

The invariable absence of fever and suppuration, in all simple fractures is indeed the most convincing evidence that the healthy body does not harbor within itself the elements of disease, and that in case of wound infection the cause does not come from within, but rather, as John Hunter correctly observed, has an outward source.

Erysipelas affords us an illustration of a disease in which the rôle of investigative evidence has been most perfected.

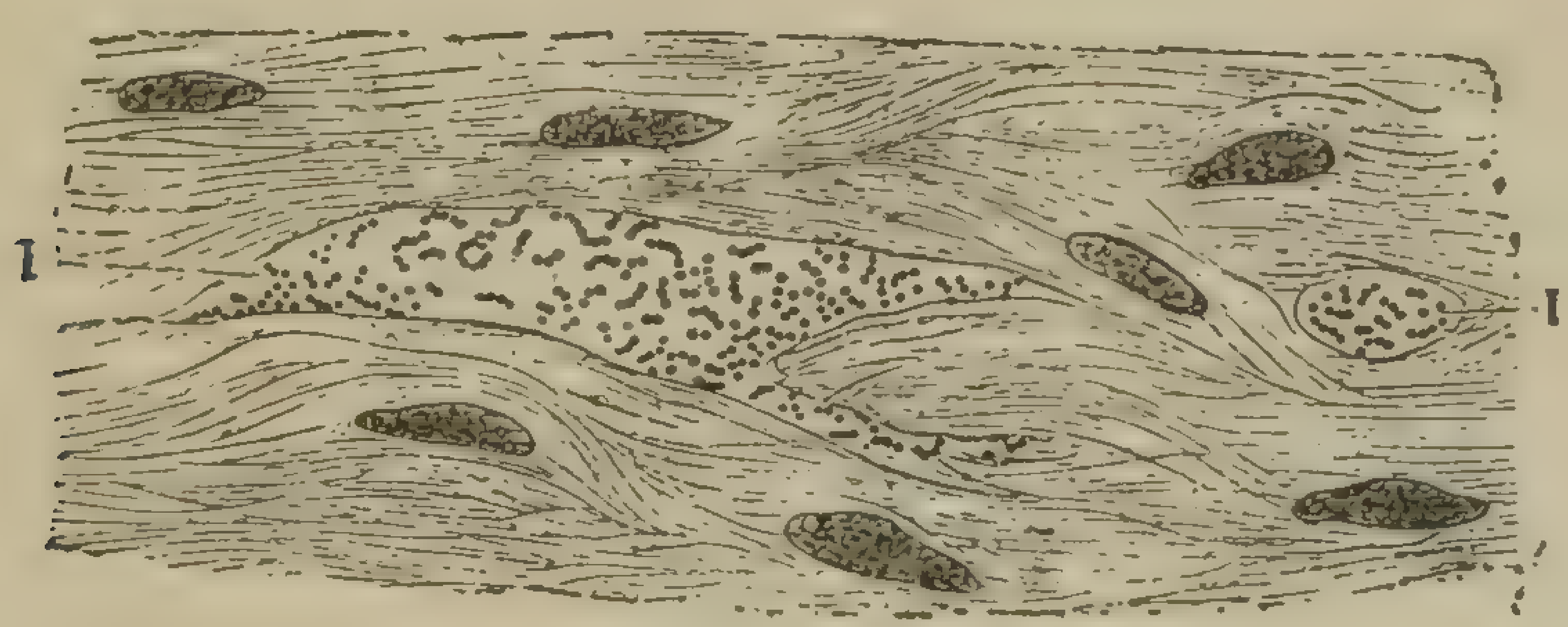

FIG. 1.

ERYSIPELAS STREPTOCOCCI IN THE SKIN (ROBERT KOCH).

Fehleisen here discovered the organism of infection, cultivated it in an artificial medium, and by experimental inoculation on animals and man demonstrated absolutely its etiological relations. The germ of erysipelas, according to Fehleisen's investigations, is a coccus which in course of its development arranges itself in chains, and is therefore a streptococcus. These bacteria, encountering a wound in the skin,

penetrate the lymph channels and connective-tissue spaces, and increase in the shortest space of time with the most extreme rapidity. In a portion of skin affected with erysipelas every interstitice is closely packed with these micro-organisms, as shown in Fig. 1. Successively new areas of the skin become involved, the streptococci forcing their way deeper into the lymph spaces.

In every part of the skin in which the micro-organisms are present, the well known and severe inflammation, clinically so characteristic, presents itself.

Hyperæmia is manifested in the intense redness of the skin and the swelling and fluctuating formation of vesicles indicate the excessive exudation of serum. As an associated condition there is extensive migration of white blood corpuscles. Thus the process is propagated until sooner or later it stops for reasons which are still entirely obscure; the organisms die and disappear, all evidences of inflammatory action subside, and usually in a short time the skin returns to its normal condition.

The streptococci are always more predominant and active in the margin of the affected cuticle, and from the latter place they may be cultivated without difficulty.

It is simply necessary to remove a small superficial portion of the skin with the scissors, and transfer it to a firm artificial medium, prepared from bouillon, when very soon the growth of the organism can be observed in places in the form of small whitish colonies. If now a tube of coagulated gelatine be inoculated by a prod with the platinum needle sterilized at white heat, small spherical colonies commence to form in a few days along the entire puncture. The most suitable temperature for the development of these streptococci is that of the normal body, so they thrive best in the incubator at 37° C.

They grow in a variety of artificial nutrient media, and

many bacteriologists have even succeeded in cultivating them upon potato.

The unimpeachable evidence that the streptococcus thus cultivated is the true cause of erysipelas, is afforded by the fact that the minutest particle of the pure culture inoculated into wounds induces the characteristic picture of the disease.

This Fehleisen demonstrated upon rabbits by introducing pure cultures into a small incised wound in the ear.

Always in twelve to twenty-four hours after such inoculation the most active inflammation was in progress. The skin covering the ear became swollen and hyperæmic, the inflammation extending in streaks, then beginning to subside after a number of days, the time varying according as a greater or less extent of surface had been involved in the disease. Still more important are the inoculation experiments conducted by Fehleisen upon patients in the Von Bergmann Clinic, with positive results. These inoculations were made for the purpose of healing inoperable ulcers and lupus patches.

Here, as in the inoculation upon rabbits, pure cultures of the streptococci were rubbed into superficial cutaneous wounds. After a certain period of incubation varying from fifteen to sixty-one hours, the patients inoculated experienced the characteristic chill; redness and swelling of the skin followed, high fever developed, and exactly as in erysipelas, occurring spontaneously, the inflammatory redness extended, then a subsidence of the entire process, with recovery, took place.

The information afforded by these simple facts makes clear to us much that was a continued mystery to the older physicians. The occasional epidemic occurrence of erysipelas, the peculiar nesting of the disease in a sick-room or in a bed, or its cleavage to some article of furniture, is now easily understood. We know that the infectious agents—the streptococci—thrive readily in organic substances, and that they

can maintain their vitality for a long time and multiply in some crevice or corner. The development of erysipelas in three consecutive patients who have undergone operation upon the same table and with the same instruments, even though placed in separate rooms, no longer surprises us. This was formerly not an uncommon observation. On the hands of the operator or upon his instruments the streptococcus was somewhere located, from here gained entrance to the wound, and caused infection with the same certainty that attends the inception of the cultures of Fehleisen.

It is indeed astonishing that the infectious nature of erysipelas had not previously been recognized, in view of the extensive experiences of the older physicians, and that the belief of Galen, that erysipelas was dependent upon a biliary consistency of the blood—*a biliaro sanguine generationem obtinet*—remained in vogue until within a comparatively few decades, so that V. Chelius in 1851 still defended it, and that Volkmann, in his well-known treatise, devoted a whole chapter to its consideration.

Another infectious disease, and indeed one of the most disastrous known to us, viz. tetanus, has also its character now fully established. In 1884, Carle and Rattone first evinced the infectious nature of human tetanus in that they produced in rabbits its characteristic symptoms, with pus taken from the seat of inoculation in patients affected with this disease.

In 1885, Nicolaier in Flugge's laboratory discovered that, widely disseminated in the superficial layers of the earth's surface, bacilli exist which, inoculated subcutaneously into mice, guinea-pigs, and rabbits, induce typical tetanus with fatal termination. Soon afterwards Rosenbach demonstrated that the Nicolaier bacillus is also present in tetanus occurring in man. After repeated failures in the attempt at growing this

bacillus, in 1889 Kitasato was successful in obtaining pure cultures, and demonstrated conclusively its tetanus-procreating qualities by a multiplicity of experiments.

A special characteristic of the tetanus bacillus differentiating it from other bacteria is its particular form, very appropriately likened to a bristle. A peculiarity which occasioned great difficulty in its original cultivation is its ability to grow only in absence of oxygen, a fact revealed by Kitasato. They develop very scantily in the ordinary culture media—bouillon, gelatin, and blood-serum. The tetanus bacillus is best grown in the manner now commonly employed in cultivation of the so-called anærobic organisms : a nutrient fluid in a tightly closed jar is inoculated, and from the material the air is completely expelled by conducting through it hydrogen gas.

The tetanus bacilli develop best at the temperature of the body—36° to 38° C.; below 18° all further growth ceases. Allowed to dry in the air, they retain their virulent properties for a long time.

When small quantities of tetanus bacilli are introduced under the skin of mice and other animals, they invariably develop genuine tetanus in the course of twenty-four hours. The region of the body immediately adjacent to the point of inoculation shows the first contractions, and gradually the clonic and tonic spasms extend to involve the entire muscular system. In two or three days, after continued and actively increasing symptoms of the disease, death occurs.

While in the development of erysipelas the proliferation of the streptococci in the tissues plays a most important part, the cocci themselves, standing in direct causative relation to the morbid phenomena, and being everywhere present in the affected areas, especially in the newly involved portions of the skin, there is in tetanus an entirely different method of the production of disease. The tetanus bacilli do not become

disseminated through the tissues, but are as a rule found only in the pus at the seat of infection. The successive involvement of the muscle groups in violent tonic spasm is not attributable to the dissemination of the bacilli, but rather is the remote effect of their toxic ptomaine products, which have been taken up by the fluids of the body, and which produce the quite uniformly fatal termination, even though the infectious area containing the bacteria be extirpated early. Brieger isolated the ptomaines produced by the tetanus germ. He found in the pure cultures of the bacillus a variety of poisonous products, viz : tetanin, tetano-toxin, spasmo-toxin, and hydrochloro-toxin, which in minute doses administered to animals are capable of producing typical convulsions.

As Nicolaier first observed, the tetanus bacilli are found in the superficial layers of the earth which we inhabit, not being entirely absent, however, in the deeper layers of the ground. Their favorite habitat is in the sweepings of floors and the dust of streets and dwellings. This explains why, as a rule, wounds develop tetanus which have been heavily contaminated with dust and dirt, and why wood splinters from the floor may be so dangerous. It may appear strange that with the enormous distribution of the tetanus bacilli the disease does not occur more frequently in wounds, but this incongruity is explained in a measure by the fact that these bacilli are not capable of developing in presence of air and in superficial wounds, and that essential to their colonization and the evolvement of their deadly properties is a penetration deep into the tissues.

As in the case of erysipelas and tetanus the germs of most of the infectious diseases have been discovered, and the cloud which so long obscured their real etiology is dispersed.

Associated as the cause of all the ordinary suppurative processes, furuncles, carbuncles, felons, phlegmons, and many

cases of pyæmia, we recognize the staphylococcus pyogenes, which in pure culture presents either a gold yellow, yellow, or whitish appearance. A frequent cause of especially severe suppurative processes and fatal pyæmia is the streptococcus pyogenes, the form and culture characteristics of which so closely simulate the streptococcus of erysipelas that not a few investigators regard them as identical, and attribute the variations in their pathological manifestations to the manner of their location in the tissues of the body.

Less frequently in suppuration other micro-organisms have been found, for instance the micrococcus pyogenes tenuis (Rosenbach).

The bluish discoloration of pus so commonly observed in excessive wound discharge, and the importance of which for a long time occasioned much discussion, is dependent upon a bacterium (bacillus pyocyanus), which produces upon all organic substances in presence of air this peculiar coloring matter that is so characteristic. Whether these bacilli can thrive only upon the surface of wounds or whether they can also permeate the tissues of the body and assume pathogenic properties is not as yet positively determined.

Bacteria are present in suppurative processes with such regularity that we may properly lay down the law in surgery that without micro-organisms there is no suppuration, at least no continued pus formation. For even though abscess may be produced by the injection of oil of turpentine or mercury without the action of micro-organisms, this suppuration differs materially from the pus formation in wounds, in that there is absence of that which adds gravity to the latter, the advancement and often unlimited extension.

The bacilli of anthrax, tuberculosis, glanders, and diphtheria have for years belonged to the organisms whose biological relations are best understood. As the cause of many,

especially cases of perforate peritonitis, investigation has recently made known to us two organisms which constantly occupy the human intestine, the bacterium coli commune and bacterium lactis ærogens, and especial germs have been found for other less common affections, for septicæmia and severe gangrenous processes. The true character of only one, and, indeed, one of the most common wound infections of former times, viz., hospital gangrene, has until now remained obscure; we hope it will continue to remain unknown. Even before bacteriological science had perfected itself equal to an investigation of this dreadful scourge of ancient surgery, the disease had vanished from our hospitals—a brilliant triumph for antiseptic wound treatment.

It would be erroneous if we were to assume that with the discovery of the micro-organisms of wound infection everything regarding these diseases was unravelled and made clear to us. We know that all continued and progressive suppurations are dependent upon the working of organisms, but the occurrence of the infection and course which it pursues afford us still riddle enough. A pyogenic staphlylococcus by no means always causes suppuration in a wound, and there are still a number of factors, as well with reference to the microbes as with reference to the tissues of the body, or rather the wound itself, which determine the occurrence of the infection, that are for the most part still obscure. Here we find ourselves merely entering upon the threshold of knowledge.

Not until recent times, for example, have we become familiar with a certain factor which in itself makes clear much that was previously occult. We refer to the variations in the virulence of the bacteria. Why infection with the same organism, for instance the staphylococcus pyogenes aureus, often presents such marked variations, is in a great degree explained by the fact that these organisms, as determined by their different

sources and many other factors entirely unknown to us, may in very large quantities be comparatively harmless, or may in very small numbers have the most extreme virulence.

Further elucidation will be afforded by substantiation of the inference of many authors, that the bacteria, found at one time in vast numbers in the saliva, at another time on the surface of the body, and again in severe suppurative processes, by reason of their morphological congruity pyogenic staphylo- and strepto-cocci, represent a whole group of varied organisms.

The investigations of Kurth and Lingelsheim tend to establish that numerous streptococci regarded as identical, upon exact investigation with reference to their growth as well as with reference to their pathogenic properties, are to be classed as a number of special varieties.

For the pyogenic staphylococci such a separation by reason of the peculiar color differences in the colonies (orange, yellow, white) is suggested, and the animal pathology tends to substantiate the view by offering illustration.

A number of septicæmias occurring quite frequently in animals, the game plague, swine plague, chicken cholera, rabbit septicæmia (Koch and Gaffkey), ferret plague (Eberth and the author), are induced by bacilliary organisms which have an exceedingly close similarity in their external appearances, but vary, pathologically, and show a slight difference in an exact comparison of their form and cultures. There can be no question that the condition of the wound and its position in the body have a positive determining influence in the occurrence of an infection and the course which it subsequently pursues. That an injury to a joint, an ordinary flesh wound, and a complicated fracture present marked variations as regards the danger of an infection, and that there are differences between a compound fracture of the lower extremity and one of the inferior maxilla, are regarded in most

particulars as unexplained facts. That a certain disposition on part of the organism can also not be excluded, is shown by a vast amount of clinical experience from which we will only refer to the peculiarly malignant course of wound infection in diabetes.

It is to be hoped that in the immediate future we will be led nearer to the solution of these problems now *sub judice*. It must, however, be borne in mind that infection in every instance is dependent essentially upon the contamination of the wound by micro-organisms. Our efforts in surgery must accordingly always be directed toward the exclusion of bacteria, and we will in this find our line of advancement in the methods in which thus far encouraging results have certainly not been wanting.

CHAPTER IV.

MEANS OF DISINFECTION.

A Variety of Agents may be Used for Combating the Germs of Wound Infection—Agents which Reduce the Virulence of Bacteria, Destroy their Poisonous Products and Confer Immunity have not thus far Accomplished much for us—Germicidal Agents—Their Application in Surgical Practice—The Principles upon which we Base our Selection of Disinfecting Agents—Limits of their Application.

THE germs of wound infection may be combated in a variety of ways. We may employ:

1. Mechanical cleansing, disposing of the bacteria by brushing, scrubbing, rubbing, etc., without affecting them further.

2. Germicidal agents, or those which destroy bacteria.

3. Agents which arrest the development of bacteria, preventing their germination and multiplication.

4. Agents which reduce the virulence of bacteria, depriving them of their pathogenic properties and rendering them incapable of multiplication in the body.

5. Antitoxic agents, or those which are not directed against the microbes themselves, but rather against their ptomaine products.

6. Agents addressed neither to the bacteria nor their ptomaine products directly, but which rather aim to exert an influence over the system, render the latter immune to invasion by infectious organisms, and increase the capability of resistance. The mechanical cleansing we may with propriety place at the head of all disinfecting methods. From time immemorial it has been extensively used in the household, and the

failure on the part of the older surgeons to recognize its value in practice was due simply to a want of proper understanding regarding the true nature of the infectious material. Since we ceased to regard the latter as a structureless miasma, and have learned that it is solid matter, often existing in the form of coarse dust and dirt, the great disinfecting value of mechanical cleanliness has become appreciated and given scientific recognition. Simple cleansing is the preparatory step in every disinfection, and scrupulous purity in surgical practice is our most important resource for the avoidance of the transmission of disease.

Regarding the means comprised under 4, 5, and 6, there is much of practical value to the physician. Toussaint and Chauveau demonstrated that anthrax bacilli may be deprived of their pathogenic properties by heating them to 40° or 50° C.

The germs continue to grow in cultures, although incapable of infection when inoculated into animals which are susceptible. Similar observations have been made with reference to other diseases. In these attenuated bacterial cultures, substances have been detected which render animals immune to the virulent organisms ; and now important data for disinfection and even therapy are being derived from these interesting observations. The investigations of Behring and of Kitasato teach us that blood serum under certain circumstances has the property of destroying bacterial products (toxines) external to and within the body. Most advance has been made in tetanus and diphtheria in the attempts at curing an infectious disease by the antitoxines of the blood serum. Specific therapeutic and prophylactic agents are now being derived from this source. It has also been found, by Charrin, that with green pus, the bacillus of which for rabbits is pathogenic, immunity against this form of suppuration in dogs and rabbits may be produced by inoculating them with pure cultures

of the germ. The same facts have been found by Reichelt to exist with reference to ordinary suppuration produced by the staphylococcus. But it is not yet positively known whether anything has hereby been accomplished for therapy in these diseases. In animals, such infections run an entirely different course from that pursued in man, and clinical observation does not tend to prove that the fact of having experienced a suppuration once confers immunity against further infection.

To substantiate this it is simply necessary to recall the course manifested in pyæmia and furunculosis. In one wound disease produced by infection, the mysterious power of immunity seems to have been entirely successful, viz: in hydrophobia. As the number of experiments in the Pasteur Institute in Paris multiply, so much more firmly does it appear established that in the toxine obtained by Pasteur from the spinal cord of rabbits inoculated with hydrophobia, and reduced in its virulence by drying, a remedy has actually been obtained with which, in a quota of cases, one of the most terrible of the wound diseases may be controlled.

Regarding the means which limit the growth of and destroy bacteria, disinfecting agents proper, after a very short and supreme reign by carbolic acid so warmly recommended by Lister, surgery has been literally inundated with old and new remedies and methods. The *criteria* which were to determine the value or worthlessness of means of disinfection were at first very imperfect, and often individuals were satisfied with and convinced of the utility of a substance, when in a decomposed fluid they were successful in causing subsidence of the odor or inhibiting the mobility of the organisms. It was the classical work of Robert Koch and his pupils which first gave us a practical knowledge of the action of disinfectants, and guided us into the channel in which we are to advance in determining positively the germicidal value of a given remedy.

First of all in testing a disinfecting method, a bacterial mixture such as afforded by decomposed fluids should not be taken, but rather the method should be tried upon pure cultures of the bacteria which are the causes of the wound infections. A certain article, for instance a silk thread, is impregnated with bacteria by dipping it into the pure culture; it is then subjected to the action of the disinfectant for a certain length of time, after which it is transferred to an appropriate artificial culture medium, bouillon or nutrient gelatin or the body of an animal. In this way it is determined whether clinging to the article living and infectious organisms are still present.

Furthermore in this method of studying the different bacteria we must carefully discriminate between the conditions in which they exist, as in addition to the simple vegetative varieties there are a number of other organisms, for instance the anthrax bacilli, which assume resistant forms—spores,—and the difference between the two as regards their power of withstanding destructive influences is so enormous that it would be erroneous to omit their consideration. While disinfecting solutions of ordinary strength, for instance a two-per-cent carbolic acid solution, are capable of destroying anthrax bacilli in one minute, the action of a five-per-cent. solution upon anthrax spores may continue for days without effect. It is therefore important to know the organisms of wound infection which form spores and those which do not. The list is as follows:

A.—Spore forming pathogenic organisms:

1. The anthrax bacillus.
2. The tetanus bacillus.
3. Bacillus tuberculosis.

B.—Non-spore forming:

1. Staphylococcus pyogenes aureus, albus, and citreus.
2. Streptococcus pyogenes.

3. Streptococcus erysipelas.
4. Diphtheria bacillus (Klebs-Löffler).
5. Glanders bacillus (Löffler-Schütz).

The power of resistance is not the same with all the bacteria. Anthrax spores are more tolerant than tetanus spores. Of the non-spore-forming organisms, the pyogenic staphylococci manifest special ability to oppose damaging influences. In the same organism the variations in the capabilities of resistance are not inconsiderable, and not only are there differences in the individual bacteria, but whole colonies, under effect of age, temperature, dryness, and other circumstances, may increase or diminish in resistance. According to the investigations of von Esmarch, *e. g.*, some anthrax spores are destroyed in three minutes by exposure to live steam, while others retain their vitality in the steam for twelve minutes.

These variations in resistance increase to a very considerable extent the difficulties in testing and comparing the different methods of disinfection. To estimate the germicidal properties of chemical agents is particularly troublesome.

Not until recently have we recognized this fact. The difficulty consists in introducing the silk thread or other article used in the disinfection, into the culture medium, or body of animals, after it has been treated with the antiseptic, without conveying small particles of the latter. The antiseptic gaining access to the culture medium deteriorates it, the germination of organisms still alive is prevented, and a reliable result is frustrated.

Even R. Koch recognized these difficulties. He recommended that the articles used in the disinfection—the silk threads—be made very small, and that the culture medium be as large in quantity as possible, so that in the diffusion which occurs after introduction of the specimen the greatest possible dilution of the antiseptic takes place. In doubtful

cases he took the precaution to free the threads of the antiseptic before making the culture test, by washing them in sterilized water, absolute alcohol, or other cleansing fluid.

It is the incontrovertible work of Geppert to have elaborated in all its bearings the importance of the transferal of traces of the substance, in testing disinfectants. Geppert showed that even the smallest particle of the antiseptic conveyed to the culture medium with the article being tested can modify materially the results of the disinfection.

An ordinary washing does not suffice ; only a complete chemical precipitation of the antiseptic leads to correct results. In the case of corrosive sublimate this precipitation may easily be accomplished by means of a dilute solution of ammonium sulfid. Geppert worked with anthrax spores suspended in clear water, to which was added corrosive sublimate in the proportion of 1 to 1000. He found that if, in the usual manner, test specimens from the material be taken and transferred to the gelatin the results will vary greatly. Often after action of the sublimate for three minutes, further growth ceases. If before being transferred from this solution the specimen be treated with ammonium sulfid entirely different results are obtained. Not only after fifteen minutes do the organisms always continue to grow, but even after an hour, and indeed, as occurred in one instance out of five, after twenty-four hours cultures could be preserved. Submersion for six to twelve minutes in a one-per-cent. sublimate solution still permitted the development of well formed colonies subsequently. Inoculation experiments upon animals also have shown that destruction of anthrax spores by a one-per-cent. solution of corrosive sublimate, continued for a short time, is not to be expected ; the spores may die in several hours, but they may also be capable of infection after the interval of a day.

Geppert's results teach us that we have thus far estimated too highly, as a rule, the disinfecting properties of chemical agents. The required chemical precipitation is not so easily accomplished in all instances as in case of corrosive sublimate; with some substances, as carbolic acid, the possibility of the precipitation is precluded. Here the traces of the antiseptic must be removed as thoroughly as possible by washing in the manner employed by Koch.

As is true with reference to all living matter, bacteria have certain definite requirements for their existence. A number of conditions must prevail, otherwise the organisms cease to grow and thrive, and sooner or later die. Of such requirements, first in importance are: *(a)* the presence of certain nutrient substances, *(b)* moisture, *(c)* a particular temperature.

These requirements of the different micro-organisms have a wide range of variation when we consider the large army of the minute forms of life. More limited are they with reference to the organisms which only interest us in this connection, viz., the germs of wound infection. The latter have a certain concordance in their mode of life, in that they are capable of growth and multiplication in the body. There are bacteria which can develop at a temperature much below ordinary room heat, and others which commence to thrive first at 60° to 70°, but the temperature which is favorable for the proliferation of the pathogenic organisms is confined within a limited number of degrees. As a rule it does not go much below +15° nor above +40° C.

We may therefore, by simply depriving the bacteria of their important requirements for maintenance, restrain their growth and finally end their existence. For thousands of years these facts have been utilized in every-day life, and in the preservation of articles of food from fermentation and decomposition, their fundamental principles have played an important rôle.

Cold and heat which go beyond the narrow limits of the above-named favorable temperature are sufficient to prevent the development of pathogenic organisms, and there are no other means which in this way work more reliably than the abstraction of moisture—the increased concentration of the nutrient media, and finally complete exsiccation.

The development of bacteria may also be prevented by adding to the culture medium chemical substances which are poisonous to the germs. The number of agents which may thus be applied is very great ; so also are they varied in efficiency.

The following list, prepared by R. Koch, will serve to give an impression of the subject.

Koch's experiments were made with anthrax spores, by drying them on silk threads, and placing the latter on small plates, each containing 10 cb. cm. of bouillon, or blood serum. Here, after a time, bacilli form and distinct anthrax threads. To the nutrient solution varying quantities of the antiseptic were added before the introduction of the threads, and by microscopical observation it was determined when the growth occurred and when it was prevented or entirely ceased.

	Decided interference with growth of the spores	Complete cessation of growth
	occurred in a solution of	
Corrosive sublimate . . .	1 : 1 600 000	1 : 300 000
Essential oil of mustard . .	1 : 333 000	1 : 33 000
Arsenite of potassium . .	1 : 100 000	1 : 10 000
Thymol	1 : 80 000	
Oil of turpentine	1 : 75 000	
Osmic acid	1 : 6 000	
Oil of cloves	1 : 5 000	
Soft (potash) soap . . .	1 : 5 000	1 : 1 000
Iodine	1 : 5 000	
Salicylic acid	1 : 3 300	1 : 1 500
Hydrochloric acid . . .	1 : 2 500	1 : 1 700
Camphor	1 : 2 500	above 1 : 1 250
Eucalyptol	1 : 2 500	above 1 : 1 000

	Decided interference with growth of the spores		Complete cessation of growth	
	occurred in a solution of			
Borax	1 :	2 000	1 :	700
Benzoic acid	1 :	2 000		
Bromine.	1 :	1 500		
Chlorine	1 :	1 500		
Permanganate of potassium	1 :	1 400		
Boracic acid.	1 :	1 250	1 :	800
Carbolic acid	1 :	1 250	1 :	850
Quinine	1 :	830	1 :	625
Chlorate of potash . . .	1 :	250		
Benzoate of soda	1 :	200		
Alcohol	1 :	100	1 :	12.5
Chloride of sodium . . .	1 :	64		

By long-continued action in concentrated solution the agents which arrest the growth finally lead to the death of the organisms which have been subjected to them. But all of these cannot yet be regarded as germicidal agents. The latter must permit of prompt application, and in such a manner as will not preclude their practical use.

Such remedies in the above named list are few in number, and many which arrest the growth of bacteria are not capable of destroying them and particularly not their spores. Cold for instance, notwithstanding its marked ability to arrest germ development, is inadequate to destroy anthrax spores, even when applied with the most extreme intensity. Pictet and Jung found that these spores subjected to a temperature of $-70°$ C. for 108 hours, and afterwards to $-130°$ C. for 24 hours, did not lose in the least either their virulence or ability to grow. Prudden showed that the pus-forming staphylococci in the interior of ice at 0° may retain their vitality for months, although naturally under these circumstances no growth or multiplication takes place.

As germicidal agents we have at our command :

1. Heat,
2. A number of chemical substances.

The heat may be applied:

a) as hot or rather boiling water,
b) in the form of steam,
c) as hot air.

The greatest disinfecting power is evolved by boiling water. It destroys anthrax spores, as a rule, in two minutes and vegetative bacteria—bacilli and cocci in one to five seconds.

Organisms which are free from spores die in water at a temperature of 60° to 70° C. in one to two hours.

Next to boiling water steam is the most powerful agent. It exerts its full influence, however, only when entirely pure—"saturated" and not when mixed with air.

Saturated steam may:

a) be quiescent (simple steam),
b) circulate freely (live steam),
c) it may be confined under a certain pressure (high-tension steam),
d) it may be heated secondarily by conducting it through iron pipes which have been raised by the flame to a temperature above 100° C. (super-heated steam).

Between the dead and the circulating steam there is, in regard to the disinfecting energy, no essential difference. While the high-tension steam, heated to above 100°, by reason of its tension works more actively, the super-heated steam appears less energetic. Live steam destroys anthrax spores in from five to fifteen minutes, according to their degrees of resistance.

Hot air is decidedly inferior to both boiling water and steam. According to the investigations of Koch and Wolffhügel, hot air at 100° C. destroys sporeless bacteria to a certainty in one and a half hours.

Germ spores on the other hand are not killed for three hours by a temperature of 140° C. The greater number of

chemical disinfectants are much inferior in their action to heat.

Only very few of these agents are capable of destroying anthrax spores positively within 24 hours. Many do not cause the death of the spores until after several days, and the greater number exert no deleterious influence upon them whatever. Comparing some of the chemical agents according to the recent investigations and those of Koch, we have to consider under :

A.—Agents which are capable of destroying anthrax spores within 24 hours :

Corrosive sublimate.
Iodine.
Chlorine.
Bromine.
Trichloride of iodine (Behring).
Cresol with sulphuric acid (C. Fränkel).

(Trichlorid of iodine is a combination of chlorine with iodine, as the name implies. The cresols contained in crude carbolic acid are insoluble in water, but are made soluble by the addition of sulphuric acid, and may thus be imparted the power of disinfectants).

B.—Agents which do not destroy anthrax spores until after several days :

Carbolic acid, 5 %, and its long list of associate coal-tar products, creolin, etc.
Crude acetic acid (about 2 days).
Chlorid of lime, 5 %, (5 days).
Oil of turpentine, (5 days).
Ammonium sulfid (5 days).
Formic acid (5 days).
Chlorid of iron, 5 % (6 days).
Chlorid of picrin, 5 % (6 days).

Quinine, 1 %, in hydrochloric acid (10 days).

Arsenious acid, 0.1 %, (10 days).

Hydrochloric acid, 2 %, (10 days).

Ether (30 days).

C.—Agents which even after months have no influence upon anthrax spores :

Absolute alcohol.

Distilled water.

Chloroform.

Glycerine.

Benzoic acid.

Ammonia.

Concentrated solution chloride of sodium.

Chlorate of potash, 5 %.

Alum.

Borax.

The circumstances naturally are different in which we have simply ordinary bacteria, bacilli, and cocci to destroy.

Here a number of remedies are efficient, not simply those in groups *A*, and *B*, but also those classified under *C*, of which we will only refer to chloroform and alcohol.

But even with these it is not the action of a few seconds, as in the case of heat ; usually a much longer time is required. The disinfecting value of chemical agents with reference to anthrax spores as well as cocci and bacilli has heretofore been over-estimated. It was believed, for instance, that 0.1% corrosive sublimate solution destroyed cocci in seconds.

When we investigate according to the foregoing method of Geppert we find that the 0.1 % sublimate solution often does not destroy the staphylococcus pyogenes and bacillus pyocyaneus with certainty in 10 or even in 15 minutes.

Still more important than knowledge of the germicidal, or antiseptic power of an agent is an accurate estimate of its

applicability in practice. The destructive influence which a remedy exerts over bacteria that are dried on silk threads or suspended in water or bouillon, is not the correct expression of its efficacy in combating the trials afforded by practice. The experiments with impregnated silk threads present relatively favorable circumstances for disinfection as may be conceived. The quantity of the antiseptic is very large, with nothing to counteract its action, and each bacillus is enveloped separately and acted upon. In practice bacteria are almost never present under conditions which render the disinfection so easy.

Usually they are found in aggregated masses and clumps wrapped in all sorts of dirt, and they may be covered by an almost impermeable layer of complex substance. These varying obstacles are overcome in varying degrees by the different chemical substances, and herein lies their choice.

For displaying the antiseptic virtues of a chemical agent nothing is more important than its solution in a substance which insures for it a permeation of the object undergoing disinfection.

As R. Koch has long since demonstrated, the strongest antiseptics dissolved in oil are ineffectual where germs dried on silk threads or existing in a state of moisture are to be destroyed, because the oil does not permeate the organisms, and the antiseptic has no opportunity to exert its influence. The circumstances are similar with reference to the dissolving in water of antiseptics which are to destroy bacteria imbedded in layers of fat and dirt. Here the strongest sublimate and carbolic acid solutions endeavor in vain to exert their effect. We may readily convince ourselves of this by the fact that silk threads impregnated with pus germs, may be laid for days and weeks in a 0.05 % corrosive sublimate solution without the bacteria being destroyed, if the threads after impregnation have

been smeared by immersing them in oil. These are factors which have most extensive application in medical practice. Not only the physician himself uses fat and oil freely in the lubrication of his examining finger, of catheters and bougies, but more frequently in the enveloping layers of fat on the surface of the body and in the interior, nature enables the bacteria to avoid the action of the antiseptic dissolved in water.

In the application of germicidal agents the chemical composition of the object undergoing disinfection plays an important rôle. It makes a vast difference in the antiseptic effect whether the bacteria are in a state of dryness or suspended in water or bouillon, or whether they are contained in bloody fluid, in sputum, or in fæces. As soon as substances are present which can enter into combination with the antiseptic, the disinfecting process is entirely modified.

We have seen above that Geppert in his tests for disinfection rendered corrosive sublimate on silk threads innocuous by submerging them for a short time in a weak solution of ammonium sulfid, the sublimate thus being transformed into the insoluble and inert sulfid of mercury.

If in practice we had a solution or a substance to disinfect which presented in a free state some sulphur combination, as hydrogen sulfid, for the sublimate to encounter, we would in a very similar manner—here however very insidiously—have, through transformation into insoluble compounds, the efficacy of the sublimate completely neutralized and an antiseptic effect precluded.

These often entirely incalculable transformations explain the strikingly unfavorable results which have sometimes been experienced in practice with antiseptics otherwise highly esteemed. In the disinfection of sputum and excreta the limited success of sublimate has become very evident.

Gerloczy was able to demonstrate that even a concentrated aqueous solution of bichloride of mercury could not disinfect an equal quantity of fæces. Here antiseptics, under ordinary circumstances weaker than sublimate, for instance, lime, are capable of a much greater action.

The efficiency of numerous chemical disinfectants is lowered by the presence of albuminous substances (proteids). This pertains to the strongest antiseptics—the metal salts, as corrosive sublimate, and to agents of the aromatic group—carbolic acid and creolin, and requires, therefore, special consideration. For this latter reason the heat must excel the chemical agents in its practical application and be more universally serviceable, as it is not subject to the extraneous influences so difficult of interpretation ; its capability of permeation is also much greater.

As regards the means of applying heat, steam and boiling water are most efficacious, and excel the hot air by an important difference, by reason of their great dissolving powers. This is especially true when we have to deal with masses of fat. The difficulties also increase when we have voluminous articles to disinfect ; for example, beds, clothing, and dressings. These articles are only with great difficulty permeated by the hot air. The investigations of Koch and Wolffhügel illustrate the conditions. The latter scientists heated among other things bundles of woollen blankets, 72 cm. long, 36 cm. wide, with a total area of 106 cm., and found in the interior of the bundles, after the heating had been continued at 152° to 160° C. for three hours, the temperature had only reached 70° to 95° C. M. Gruber observed that the temperature of a bundle of woollen blanketing material was raised to 100° C. in all parts, only after 107 minutes, while the same temperature was accomplished by the steam in 8 minutes.

In the application of a bactericidal agent, the time in which the destruction of the organisms is effected also comes into

question. Where the disinfecting process is required to destroy spores in minutes and the ordinary bacteria in seconds, chemical agents are entirely inapplicable, because, for their action a longer time is necessary. In the utilization of heat, boiling water and steam are superior to hot air. The consideration as to what extent the objects acted upon suffer under the procedure is of extreme importance in the selection of chemical and physical means of disinfection. A number of very excellent antiseptics are, *a priori*, for the disinfection of certain objects absolutely excluded. For instance, corrosive sublimate cannot be used in the sterilization of metal instruments, as it corrodes and damages the latter, and, as is self-evident, high temperatures are inapplicable in the disinfection of objects organic in structure, foremost among which are the hands of the physician and the skin of the patient. The promiscuous application of chemical agents is excluded by reason of their poisonous effect upon the body. Hot air cannot be used for asepticizing dressing materials, as, by its continual action for hours it makes the articles fragile.

We have, therefore, in the work of disinfection, never simply a single problem, but rather a whole series of fundamental principles to bear in mind. We must consider :

I. The composition of the object to be disinfected.

II. The resistance of the infectious organisms to be destroyed or impaired.

III. The disinfecting power of the agent to be applied.

IV. The resistance which may be offered the agent through

a) the form and shape of the object,

b) by layers of fat and dirt,

c) by chemical changes.

V. The time occupied by the process.

We may add still further without the necessity of special argument :

VI. That which the method demands as regards experience and knowledge on part of the operator.

VII. The question of expense.

An antiseptic which, under all circumstances, meets all demands, of course does not exist. According to the individual conditions one sterilizing procedure is to be preferred at one time, and some other at another time.

The range of utility of chemical agents, formerly very extensive, should, as the result of recent investigations, be decidedly limited. Most universal, on the other hand, must be made the application of heat which, by reason of its great germ-destroying property, permeating propensity, and readiness of application, greatly excels the chemical agents.

Very frequently a single method of sterilization does not suffice and we are required to use several together or in succession. Thus the mechanical removal of bacteria-laden dirt must precede nearly every cleansing. Then we often succeed by a combination of chemical agents with one another or with heat (boiling soda solution).

It will be the purpose of the coming chapters to discuss in detail the disinfection of the articles coming into question in connection with the subject of wound treatment.

We will here only refer briefly to one point regarding which a correct understanding is necessary in advance. This is what is practically worthy of effort and what may be attained by disinfection.

At the beginning of the antiseptic era, response to the inquiry of what should be accomplished was very short and concise. It was simply stated that all bacteria must be destroyed. At that time, however, men were not familiar with the peculiar biological characteristics of the micro-organisms; they did not know that persistent forms (spores), aside from the ordinary bacteria, existed, which are endowed with a

power of resistance to damaging influences, such as is unknown elsewhere in the living world. We understand, to-day, that there are a number of spores which can withstand boiling and steaming for hours. We also know that spores of the hay bacillus and of surface earth, after two hours in circulating steam, have still been found alive; and Globig made us acquainted with the spores of a bacillus, living on potato, which after boiling in water for four hours may retain its vitality.

If we were to regulate our instructions for disinfection by this latter organism, which through the medium of its spores represents the maximum of resistance, we would boil and steam for hours the articles required in practice, in order to really destroy all the spores present, and thus inaugurate rules which would for the physician be impracticable. The germs to which we here refer are, however, never pathogenic for man, and we must simply bear in mind that organisms which do not damage our wounds need not be taken into consideration in our disinfecting regulations.

Animal pathology affords us illustration of extremely resistant pathogenic bacteria. Thus the spores of black-leg (Rauschbrand) and malignant œdema bacilli are far more resistant than anthrax spores. It is very possible, if not positively proved, that both these diseases also befall man, and it is indeed cogitable that the peculiarly destructive and severe gangrenous inflammations which occasionally occur in the human, and which bacteriologically are still very obscure, are dependent upon similarly resistant organisms. These cases must, however, be treated as what they still are, viz., exceptions. With them, then, the disinfecting measures may be more rigidly enacted, and the articles which the suspicious virus has encountered, more cautiously sterilized than otherwise.

In addition, we must make a discrimination between the

different wound infectious organisms which, in the immediate results of inoculation experiments in the laboratory, appears to almost vanish, but which in practice assume increased prominence—the difference between pathogenic and infectious. Not every disease whose cause is a bacillus is equally infectious, because the germ can, by experiment, always be inoculated successfully from one animal to another. All evidence points to one of the most dreadful diseases, viz., Noma, or, in common parlance, water-cancer, being due to a bacillus which proliferates to an enormous extent in the affected tissues, inducing gangrene ; and still this disease is never more than sporadic—at least occurring in but a limited number of cases at one time, never assuming the character of a true epidemic, and never, as far as can be determined, being transmitted from one individual to another.

So also is the danger of the complication of wounds by diseases which are even of frequent occurrence by no means always equal.

To illustrate this, in clinics and hospitals tubercular affections are treated by operation daily, and very often the tubercular material is not at all cautiously disposed of ; still almost never has the infection of a fresh wound by tubercular virus been observed. Thus do we find the older clinicians regarding anthrax as transmissible from animals to man, but contending that a conveyance from man to man is not to be feared ; and it is a fact that the latter communication with our present improved methods of observation has seldom been seen. On the other hand we know very positively that erysipelas and suppuration occur in wounds successively, implicating one case after another where the wounds are neglected and a liability to infection ignored.

Our disinfecting measures should first be directed against those organisms which are really infectious, and it is to be

regarded as special fortune that they are of the class which are lacking in spore formation, and which therefore are most easily destroyed. If through our aseptic appliances we have succeeded in excluding from our wounds suppuration, erysipelas, and septicæmia, we have pretty thoroughly completed our task. When, in our instructions for disinfection, we take the destruction of anthrax spores, which as a rule represent the maximum of resistance, as the standard, we have placed the latter sufficiently high to cover the majority of, and in all probability all, cases.

This however does not prevent our cleansing the instruments with special thoroughness after an operation, in case of purulent œdema. Herein lies the art in discriminating and not making a routine of one line of practice.

CHAPTER V.

DISINFECTION OF THE SURFACE OF THE BODY.

Upon the Surface of the Body, a Variety of Micro-Organisms are always Present—Disinfection of the Skin and Hands—Disinfection of the Mucous Membranes—Disinfection of the Utensils Necessary in Cleansing the Skin—Soap, Brushes, etc.

SINCE Eberth, in 1875, demonstrated the presence of various bacteria in normal perspiration, and described the colonies which they form upon hairs, a number of investigators have interested themselves in the germs on the surface of our body, and, as a result, there have been discovered a great profusion of organisms.

While the tissues in the interior of our body are free from bacteria, the outer surface simply swarms with organisms of the most varied species—moulds, yeast fungi, bacilli, cocci ; and color- and odor-producing bacteria are present in numberless herds. And this is not surprising, as all the conditions which the lower organisms require for their existence, are found associated upon the surface of our body. A uniform temperature favors their growth, the secretion of the cutaneous and mucous glands provides the necessary moisture, and dead epidermal cells, animal and vegetable substances of the most varied origin, afford the necessary culture-medium. With our present technique it is not difficult, even by the most superficial investigation, to convince ourselves of the presence of these numerous microbes. It is simply necessary to press a small cover-glass on to the moist skin or mucous surface, or place an epidermal scale

upon a glass slide, and wash it in dilute acetic acid or liq. potassæ; then, after drying and heating the specimen for a short time in the spirit flame, color it with methylene blue; after which under the microscope the various micro-organisms will be seen. It is true we have not as yet been successful in separating out of this conglomeration a special class, or a number of special varieties, as particularly epithelial germs; it appears to be rather a diversity of forms which are present. In a very fluctuating way, first one variety and then another is predominant. The opinion of Bordeni, that the inhabitants of every land and every region have their special and peculiar epidermal bacteria, may be accepted as correct; indeed individuals of every occupation may have their characteristic germs nesting upon them, according as their avocation brings them in contact with different organisms. We encounter bacteria with extreme frequency; and they adhere to the surface of our body with such readiness, that after only a transitory contact with a material containing germs its distinct traces will be found upon the individual, even though apparently perfect cleansing be practised. Nothing in this particular is more instructive than the observations of Fürbringer. This scientist engaged in work for short intervals in his garden, and found that, even after washing his hands, various garden bacteria remained about the finger nails. At another time he handled specimens of urine, and later investigations revealed to him the presence upon his hands of numerous germs of the micrococcus ureæ group, which are the cause of the alkaline fermentation so frequently observed in voided urine.

The regions which are covered with hair, also those in which the product of the sweat glands is especially abundant—the axillary space, the interdigital folds, and the furrows about the anus,—are the places of predilection for the bacteria upon our cutis. The oral cavity (Miller) and the entire

intestinal tract harbor, normally, myriads of micro-organisms. In the genital tract of the female, as far as the os uteri internum (Winter), also in the upper respiratory passages and in the outer part of the urethra, large masses of schizomycetes are present ; and so are the conjunctival secretion and the cerumen of the ear rich in germs of the same nature. These microbes, already vast in numbers, often increase to an almost incredible extent after only slight disturbance in the normal superficial continuity. An augmented secretion, a slight catarrh, or a mild degree of eczema, causes the thousands of germs to multiply to as many millions, and innumerable becomes the host when there is a suppurating wound, a fistulous tract, a superficial ulcer, an ichorous cancer, or similar conditions. We must confess that it is not as yet positively proven, whether the germs of pus formation so much feared, and the genitors of the severe pyæmic and septicæmic processes, belong to the regular and customary micro-organisms of the surface of our body. Occasionally, according to all observations, they are present, and the luxuriant development which normally exists, implies that as the various non-pathogenic micro-organisms find upon the cutaneous and mucous surfaces the conditions necessary for their growth and proliferation, so also may the pathogenic bacteria colonize upon our body as our avocation or incident exposes us to them.

The cleansing of the surface and the removal of the numberless adherent organisms, perhaps pathogenic, is one of the most important duties of asepsis. Wherever a wound exists or must be created, the region in the vicinity for an extended distance demands a thorough disinfection, in order to preclude the entrance of septic germs into the depths, and prevent the induction of the disturbances so much feared in the course of repair. The hands of the physician require even more thorough disinfection than does the skin of the patient before

they approach a wound. It is this latter source which is the most to be feared in infection; for, by continued contact with pus and inflammatory products, the physician's hands are especially liable to be the recipient of the noxious elements of disease, and the latter adhere to them. At no time should the surgeon consider more the *πρωτόν μή βλαπτειν* of Hippocrates, than when he is about to approach a wound with his hands. And no wound is an exception in this regard; because, even though already in an abnormal condition, it may be still further infected. To laudable pus formation erysipelas may be added, to erysipelas sloughing, and superinduced upon all these we may have purulent œdema or general sepsis. The disaster which was formerly, and at the present time is frequently caused in wounds by the unclean hands of the physician is barely conceivable, and numberless times when wounds have been entered with a view to aiding and inducing repair, instead of the health and life of the patient being maintained, severe suffering and death have been occasioned.

Unfortunately the thorough disinfection of the hands is exceedingly difficult, and the demands here presented for obtaining asepsis are the most toilsome and exacting. At the beginning of the antiseptic era, when belief existed in the great germicidal power of carbolic acid, the disinfection of the hands was regarded as easy. A simple and even short immersion in a 2 to 3 per cent. carbolic acid solution was considered fully sufficient to justify the claim for a disinfection. In one of the most popular guides to antiseptic wound treatment, that of Watson Cheyne, 1882, we read that the preliminary washing of the surface with soap and water is superfluous. To-day we entertain entirely different ideas, and in the decennium which elapsed since the pupils of Lister have accepted the foregoing opinions, practice

and experiment have proven conclusively of how little value is the immersion of the hands in carbolic acid, and how important is the application of soap and water, disregarded by Watson Cheyne. It is consistent to assert that a simple immersion of the hands in even a very strong antiseptic solution is of practically no value as far as disinfection is concerned. If the germs here were as easily destroyed as they are when present in bouillon cultures or dried upon silk threads, we might, at least after a long-continued action of the antiseptic solution, expect some effect; but just the most difficult conditions for the disinfection—the imbedding of the bacteria in fat and layers of dirt, the concealment in deep furrows and niches, in substrata rich in albumen and inert organic material, are present on the surface of the body. Even the strongest antiseptics exert their effects in vain upon these mantels of dirt; the sublimate solution rolls in drops from the fat glistening surface without even moistening it. In the folds of the skin, in the depressions about the nails, and in the space under the nails, the number of bacteria remains practically unaltered after use of the sublimate.

Since Kümmel and Fürbringer outlined the scientific principles underlying the disinfection of the skin and hands, a number of investigations into the subject have appeared, and the chapter of the disinfection of the skin has now its own extensive literature. In the essential data resulting from the investigations of these two authors there has, however, been no change.

The dissolving away of the bacteria-enriched dirt, through application of the largest possible amount of warm water and soap, with the additional aid of alcohol and ether (Fürbringer), and the mechanical removal of the dirt by use of the brush and rubbing with towels, have always been given as the prime factors of importance in the disinfection of the

skin. The number of antiseptics, recommended anew for the disinfection of the hands, with claim to superiority, is very great, but here also chemical agents play a subordinate rôle. Many operators in the disinfection of the skin dispense entirely with antiseptic agents, confining themselves simply to the scrupulous and careful cleansing, thereby attaining brilliant results.

The disinfection of the patient's skin and the hands of the physician is not dependent upon the question of one antiseptic or another; it is rather a matter of personal dexterity and painstaking thoroughness. The choice of the antiseptic is to be determined by the individual, the sensibility of the skin, etc. It is difficult to state just how long a person should soap and brush his hands; as may be readily understood, the experienced and skilled worker would accomplish more in a brief interval than one who is superficial and careless in ten times as long a time.

In the v. Bergmann Clinic, the disinfection of the skin by the supplemented Fürbringer method is practised as follows:

1. The surface is actively brushed for at least one minute with soap and water, as hot as can be borne.

2. It is carefully rubbed and dried with sterile towels or pieces of gauze. In doing this the niches and crevices are given special attention, being scraped out by means of small metal nail-scrapers. The space under the finger nails requires particular notice, as, according to Fürbringer, Mittmann, and Preindelsberger, there are more germs present here than on any other part of the hand.

3. The skin is rubbed for about a minute with 80 per cent. alcohol aided by a pledget of sterile gauze.

4. The surface is washed with a ½ per cent. sublimate solution, and rubbed with gauze pledgets.

When the skin is very dirty, as is often the case with labors, or where there has been excessive desquamation in consequence of the long envelopment in bandages, it is advisable, previous to beginning the foregoing disinfecting procedures, to rub the surface with ether. The latter removes gross dirt most effectually. The presence of very tenacious substances, or the previous contact with especially infectious materials, is an indication for a repetition of the disinfecting procedure outlined. The physician must further take the precaution not only to disinfect himself before an operation and examination, but also after the contact with all infectious substances; particularly should the cleansing be thorough after dealing with suppurating wounds,—at least in the interest of personal safety,—to prevent the septic germs from resting upon the hands and becoming adherent.

In cleansing the patient's skin, especially in the region of the buttocks, the bath plays an important rôle. One or a number of baths should, when possible, be administered previous to operations, and good bathing regulations in surgical hospitals are among the most important adjuncts to the aseptic appliances. If the bathing of the patient is impossible, washing with soap and water should be the more thorough with view to substituting the bath. For an ample distance in the neighborhood of the wound or area of operation the part should be shaved, not simply for the purpose of removing the hair upon which many germs always aggregate, but also for disposing of the superficial epidermis which, as a rule, is heavily impregnated with micro-organisms. Upon the head, for cosmetic reasons, the use of the razor has a certain limitation, although here also, even in minor cases, as simple cutaneous cuts or superficial incisions, the hair should be removed for 3 to 5 centimetres from the margin of the wound. After shaving, another application of the soap and brush is made,

the part being then rubbed with alcohol and dried with towels.

If the surgeon has completed this important mechanical cleansing, he can with certainty calculate upon its results.

An aseptic operation would, of course, not be undertaken, unless it were a necessity, directly after making an autopsy or incising a phlegmon, but when the circumstances did demand such procedure we would not hesitate in exercising it after energetic and repeated application of the disinfecting measures recommended.

Several times it has been proposed that the physician coat his hands with a firm paste which would fill out particularly the grooves about the nails and the furrows. The paste being made of an aseptic material, such as carbolic acid, camphor, and an excipient (Schneider), it was thought that it would act as a safeguard against the transmission of germs. Further than being an ingenious thought, there is nothing of value in this proposition, as there is no paste which can be spread over the hands, and adhere to them, and be sufficiently elastic and firm to tolerate every manipulation. Such coatings naturally soon become brittle and scale off, and the conditions of uncleanliness are greater than before. Simply the oiling of the hands we consider of value under certain circumstances; not to prevent the giving off of probably adherent germs, however, but solely to avoid their becoming contaminated. When the hands are thoroughly oiled, the bacteria, which are suspended in watery solutions, adhere less readily, and are more easily removed. This is the principle underlying the judicious lubrication of the hands in vaginal and rectal examinations, and in the making of autopsies.

Much more difficult of disinfection than the hands are the mucous membranes. Complete asepsis here is absolutely im-

possible. Operations upon the bacteria-enriched mucus tracts are devoid, therefore, of all certainty as regards an aseptic course of repair, such as we have in our power to insure in operations upon the skin, which permits of absolute disinfection. For this reason we are required to conduct the wound treatment differently in the former instance than in the latter, to aim less regularly at securing primary union, etc. If a simple irrigation with a strong antiseptic solution would disinfect the mucous membranes there would be no further difficulty, but the most powerful antiseptics are here worthless, as in securing asepsis of the skin, and the irrigation of the vagina with a solution of 1:1000 corrosive sublimate has not the slightest influence over the number of bacteria present (Steffeek). The application to the mucous surfaces of any strong chemical solution is always hazardous, because, with the enormous propensity of most membranes for the absorption of fluids, the danger of an intoxication is very great. Profuse vaginal irrigation with sublimate has often caused severe poisoning, and flushing out of the rectum with a solution of bichloride might, with the capability of its mucous membrane for rapid absorption, lead directly to death. Furthermore, most antiseptics irritate the mucous membranes, cause an active secretion, even a catarrh or an actual erosion and destruction, and thereby induce conditions quite the opposite to what we would attain—an increase instead of a decrease in the bacteria. The only method by which it is possible to accomplish a disinfection of these parts is here again the simple mechanical washing or inundating, the rubbing out with the fingers, with cotton or gauze pledgets—the mechanical removal of the mucus and dirt. Simple warm water or some mild irrigating solution is best adapted for use in this connection. Weak boracic acid, a dilute solution of permanganate of potash, or of

acetate of aluminum, boiled physiological solution of common salt, and especially in operations in the mouth, the camellia tea, held in such high esteem by the laity, find appropriate application. In operations upon the intestinal tract, we should endeavor to secure the most thorough possible removal of the bacteria-laden contents, and therefore a preparatory course of treatment extending over a number of days is necessary. When the rectum or intestine is to be the seat of operative interference, a thorough purgation should, when permissible, be ordered and enemas administered, as in operations upon the stomach, where repeated lavage is to be practised.

In the use of cathartics, mild remedies are to be preferred, as oleum ricini or magnesia sulphate. It has been supposed that an influence can be exerted upon the bacteria contained in the intestine, by means of drugs, although this has never been proved. Stern failed to observe any effect from the use of various disinfectants which have been recommended, as calomel, salol, napthalin, naphthol, camphor, thymol, quinia, red wine, etc.

In the disinfection of the skin and mucous membranes it is understood that all materials used in the procedure are themselves to be aseptic, so as not, perhaps, to produce infection instead of cleansing. For instance, the physician must undertake the disinfection of the patient's skin with his own hands disinfected. With reference to the water used in cleansing we will direct attention to what is said in Chapter XIII.

Gauze, cotton pledgets, and towels for rubbing the surface must be sterilized in steam, although in case of emergency newly washed towels may be used without further attention, as they are practically free from germs if they were not subsequently contaminated. The alcohol, ether, or oil of turpen-

tine employed for removing the fat is kept free from germs only by somewhat careful handling. With reference to the soap, v. Eiselberg showed in 1877 that that which had been boiled in course of its manufacture must be aseptic. Only in the case of hasty preparation where, in the saponification, the animal fats, often heavily laden with bacteria, have been mixed with the lye, cold, will micro-organisms be found present in the soap, and concerning this latter point individuals must require a guaranty of their suppliers. The bran of almonds, now in limited general use, always contains bacteria in abundance, and can be applied only after thorough sterilization ; it had better entirely be dispensed with.

The brushes require the most scrupulous attention, and unfortunately it is they which, as a rule, receive least notice. These articles are allowed to lie carelessly about commodes for weeks or even months at a time, and are then used directly in disinfection. It is evident that a brush which has served for removing from the physician's hands pus or masses of fæcal matter, will take up these substances in a large measure, and after being thus infected will, in its further usage, disseminate the germs which are adherent to it. Furthermore, brushes much employed are moist, as a rule, and by reason of the quantity of albumen which they absorb in the form of desquamation, pus, and blood, they become genuine culture habitats for microbes. Repeated investigations have shown that the brushes used in hospital wards, autopsy rooms, and laboratories contain innumerable germs. Even after a single application in the disinfection of the skin, many thousands of micro-organisms, as readily conceivable, may be received into the brushes (the Author and Spielhagen).

Practitioners who have come to recognize this defect in our disinfecting measures have endeavored to remedy it in various ways, one to asepticize the brushes frequently, another

to have new brushes provided for each major operation, and finally it has been thought best to dispense entirely with brushes, and adopt some substitute. Thus Neuber, convinced of the deficiency of cleanliness in the hand brushes ordinarily employed, and believing in the impossibility of a safe disinfection of them, excluded the brushes entirely from his instrumentarium, substituting bundles of wood fibre, which could be destroyed after a single application. These articles, already in use in many households for scrubbing, may be sterilized in steam, can readily be prepared in large quantities, and are so inexpensive that even in extensive operative practice the cost would not enter into consideration; for each cleansing new articles could be used. Unfortunately, however, the bundles of wood fibre cannot entirely replace the brushes, as that which the latter can only accomplish, the thorough excavation of the niches, angles, sinuses, and furrows in the skin, cannot be attained by crude bundles of wood fibre. To the principle of using new brushes for each operation there can, on grounds of asepsis, be no objection; dispensing with and destruction of, is always the better disinfection, but, considered from the standpoint of cost, it is impracticable in the majority of instances.

The ordinary brushes, and especially the much used, cheap hand brushes, made from wood and pigs' bristles or fibre, are by no means so difficult to sterilize. Most effectual in maintaining asepsis is the continued immersion of the brushes in a ½ per cent. sublimate solution. Even brushes very much used will, when continually laid in sublimate, usually be found free from germs. But when brushes have been infected with pus and tenacious dirt rich in fat, the sublimate solution no longer suffices, the

special difficulty being that it does not act quickly enough. It would therefore be well to boil the articles which are heavily infected after they have been used, or sterilize them in steam, and to make a practice of treating them in this manner before every major operation. The enormous difference between the disinfecting power of boiling water and sublimate solution becomes very evident when we attempt to sterilize a brush heavily infected with ordinary pus. While the bacteriological conditions remain unchanged after a ten minutes' action of the sublimate, immersion for one minute in boiling water insures complete asepsis. The great value of the continued laying of the brushes in sublimate consists, first, in the prevention of the development of bacteria which have been received upon them, and second, in the gradual, if not rapid, destruction of the germs in the long intervals of their non-usage. Upon every physician's wash-stand there should be a receptacle containing a brush immersed in sublimate solution as a necessary aid to thorough cleansing. The brushes tolerate very well being immersed in sublimate for weeks, in fact they are improved by the immersion, becoming softer. When only moderately used, a single daily renewal of the antiseptic is sufficient, because the disinfection is not disturbed, excepting when soap-suds gain entrance to the solution, as relative investigations have shown.

The care of the brushes in the von Bergmann Clinic is practised in the following manner :

1. The new, unused articles are placed for thirty minutes in live steam.

2. The brushes are kept continually submerged in $\frac{1}{2}$ per cent. sublimate solution, renewed at least once daily.

3. After very intense usage they are washed in hot, and

finally in boiling water, before being returned to the sublimate.

Upon every washstand are placed enamelled receptacles for the soap, and the bichloride in which the brushes are contained.

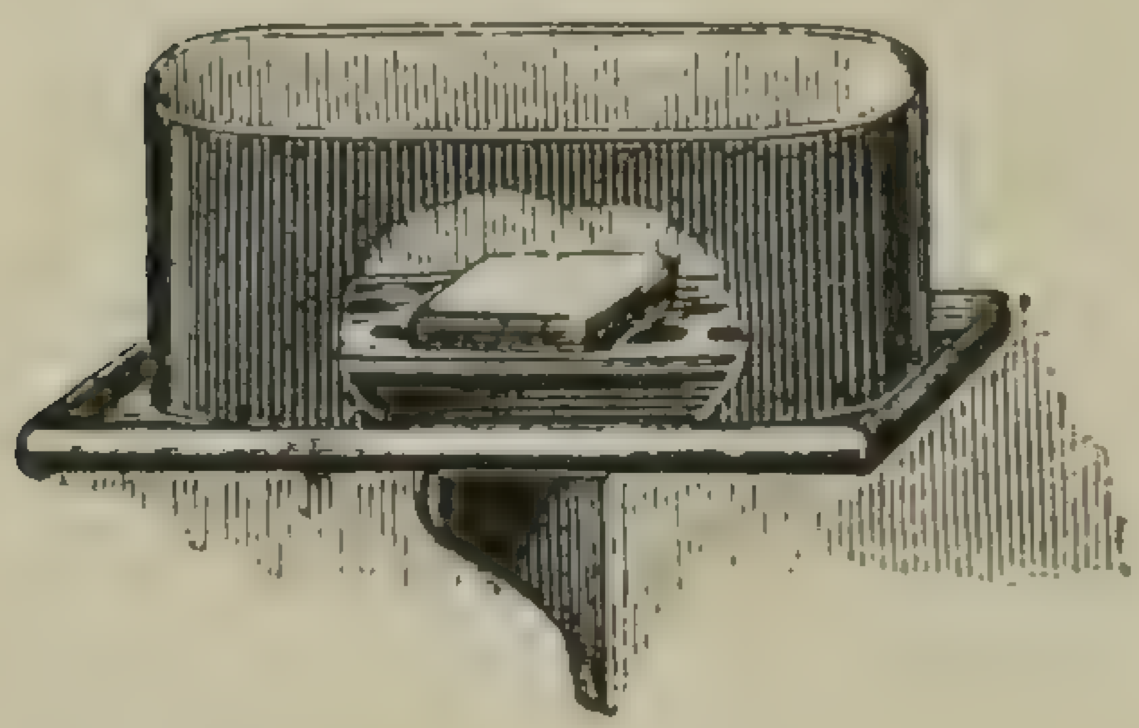

FIG. 2.

SOAP RECEPTACLE.

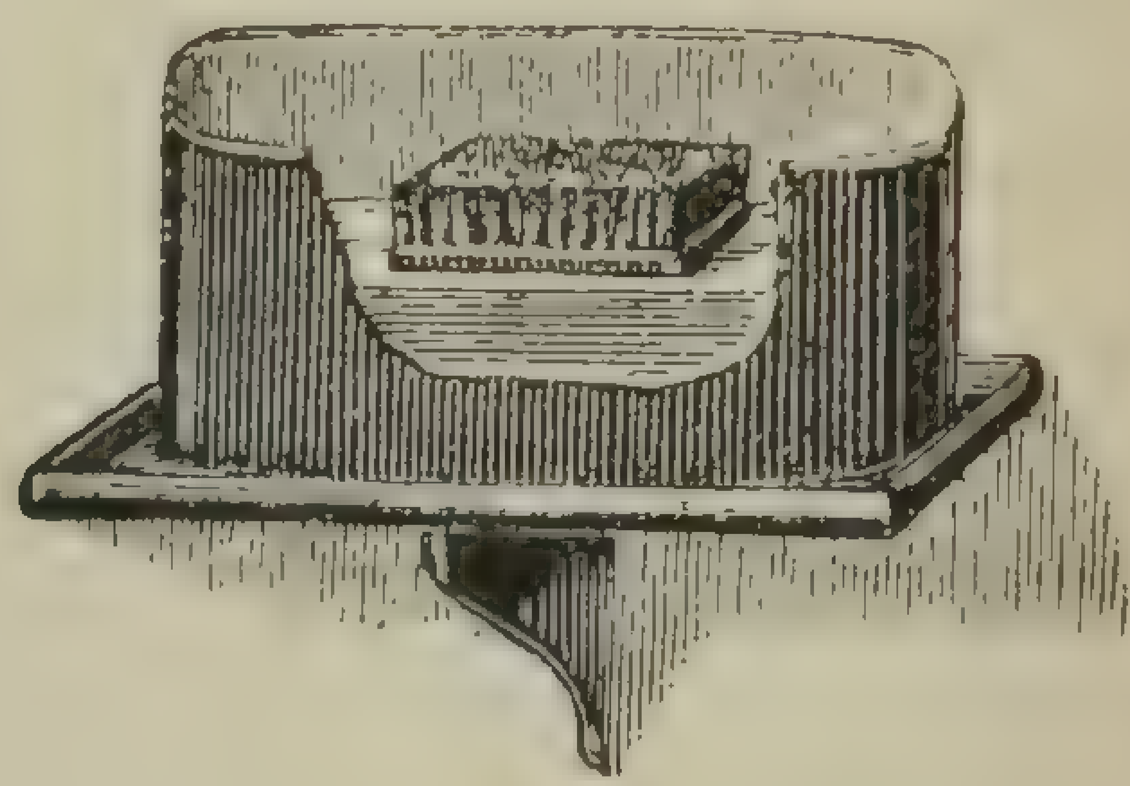

FIG. 3.

RECEPTACLE IN WHICH HAND BRUSHES ARE KEPT IN SUBLIMATE SOLUTION.

CHAPTER VI.

STERILIZATION OF METAL INSTRUMENTS.

Laying the Instruments in a Weak Carbolic Acid Solution Previous to Operation does not Suffice—Importance of Mechanical Cleansing—Heat Sterilization of Metal Instruments—Sterilization in Hot Air—In Steam—In Boiling Water—Sterilization in Soda Solution—Superiority of the Latter—An Apparatus for Sterilizing Instruments in Soda—The Composition of Instruments.

ALL instruments which come in contact with wounds require the strictest aseptic cleanliness. The amputating knives, saws, and forceps, and even the popular sounds so often dangerous to the patient, must be sterilized with the greatest care. With just as much precaution as that demanded in the disinfection of the metal instruments must we deal with the other articles which are employed in our daily practice, which circumstances require us to use in fresh, aseptic wounds, and then perhaps employ about those highly infectious, sanious, and suppurating. The rule observed with reference to the bandages, gauze, absorbing pledgets, sponges, drainage-tubes, etc., that of promptly destroying them after they have once been used in cases of sepsis, at least not employing them again about fresh wounds, even though disinfected, cannot, of course, be applied to the instruments and certain implements used, nor to the objects of their application. It may occur that the surgeon who has operated upon a phlegmon is necessitated shortly afterwards to use the same instruments in the relief of a strangulated hernia.

Up to the present time it has generally been customary to lay the metal instruments a short time previous to, and during operations, in some antiseptic fluid. Solutions of carbolic acid for this purpose have been the most popular. We must not miscalculate, however, the strength in which this solution can be applied for this purpose. We do not here refer so much to the action of the antiseptic upon the instruments—to the fact that the knives lose their edge by long-continued submersion, for instance—but more especially to the effect upon the individuals who employ the instruments. The continued use of a 5 per cent. carbolic acid solution is impracticable on account of its effect upon the hands. Even a 3 per cent. solution is intolerable in long-continued or protracted operations where the instruments have to be handled for hours in the carbolic acid solution and this repeated, perhaps, for days in succession.

Individuals who, as a rule, are not especially sensitive to antiseptics, suffer from an intense maceration of the skin covering the hands, if not from an actual eczema; and not infrequently there occurs carboluria and more or less constitutional disturbance.

With or without the knowledge of the operator the attendant handling the instruments reduces the concentration of the solution, in order to obviate these unpleasant effects. In the von Bergmann Clinic the carbolic solutions formerly employed for disinfecting the instruments were never used stronger than 2 per cent., and even in that degree of dilution could be tolerated continuously only by exceptional individuals.

When we consider the fact that the instruments in being used become covered with blood, pus, and masses of fat, we would, upon recalling what has been said in Chapter IV. regarding the effect of the ordinary antiseptic fluids, and especially the short application of a 2 per cent. carbolic acid

solution, conclude that not much importance is to be attached to them. Even though good results have been obtained, and many operators are still satisfied with this method, we are by no means to attribute these favorable occurrences to the weak carbolic acid which has been poured over the instruments a short time previous to the operation, but rather to the co-operation of other factors of the preparatory technique. If the instruments after each operation had not been subjected to a thorough and careful cleansing with soap, water, and brush, then rubbed and dried, and thus introduced into the carbolic acid in a condition of more or less perfect asepsis, the results might indeed fail. When it happens that we are required to undertake in succession several operations with the same instruments which have simply been laid in carbolic acid—operations under infectious as well as aseptic conditions — we soon become convinced, through complications which occur in the wound's course of repair, of the ineffectual disinfecting power of carbolic acid. The sterilizing value of the latter comes to be regarded as almost nil ; it possesses the single advantage of being a tolerably aseptic fluid in which the instruments can be submerged during an operation. The chief thing of importance always in disinfecting our instruments is the mechanical cleansing to which they must be subjected after each usage. The pus, tissue particles, masses of fat, and dried blood—the favorite habitats of microbes—must be removed by mechanical means. In the von Bergmann Clinic this has for years been done by first thoroughly irrigating the instruments with ordinary water, then laying them in a solution of hot soda and soap, and cleansing them thoroughly in every part with a brush. They are then re-irrigated and rubbed with alcohol and chamois. A final rinsing in, preferably, soda solution, and careful drying, closes the procedure.

By this manipulation particles of pus and other forms of gross uncleanliness are effectually removed, but from the nature of things it does not follow that the instruments are absolutely aseptic. They contain still many varied forms of organisms which are often found strewn in great profusion over the surface. The numbers of germs which we have observed, however, in bacteriological investigations were not great, and depend upon whether the instruments are easy or difficult of cleansing, whether plain or containing many notches and crevices.

As stated, this simple mechanical cleansing has in many instances proved sufficient, and may still suffice ; but for the metal instruments we have now at our disposal reliable sterilizing procedures applicable without difficulty, and we are not required to resort to a method the thoroughness of which it is difficult to control. Metal instruments may be sterilized :

1. In hot air.
2. In steam.
3. In boiling water and other boiling fluids.

These are the most efficient means with which we are familiar.

Hot air, long ago introduced for sterilizing instruments in the bacteriological laboratory, has been continued, and in recent times has been highly recommended for surgical purposes. For a few years it appeared in fact as though the method was going to be permanent and used extensively by physicians. The hot air, by its energy in destroying bacteria and by its capability of permeating enveloping layers of fat and dirt, does much excel the chemical disinfectants (see Chapter IV). In order to free instruments of sporeless bacteria, a disinfection of several minutes' duration would suffice, but for the destruction of anthrax spores a heating for three hours at 140° C., or a temperature of 150° to 180° C. continued

for two hours, would be necessary. In the Berlin Royal Clinic there have been repeated attempts made to utilize hot air in the sterilization of metal instruments. But the method soon demonstrated itself to be impracticable, and now we are of the opinion that, while hot air may be employed for certain purposes, it is not to be used generally in medical practice. It is too difficult of application and occasions great loss of time.

The time necessary for the destruction of any resistent spores by heat at 150° to 180° is about two hours; to raise the temperature of a well constructed air-sterilizer to this height requires about 20 to 30 minutes, and to cool off the intensely heated instruments nearly the same length of time. Thus the whole sterilizing process involves about three hours. Is such a method to be employed in practice? Consider for a moment the task of uniting the severed tendons produced by a wound through the flexor muscles of the forearm, and the sudden associated encounter with an incarcerated hernia, and we would soon abandon the idea of employing a sterilizing procedure of several hours' duration. Poupineal (1888), who was an active advocate of the hot-air sterilization, purposes, in recognition of this difficulty, to sterilize all the instruments on the day preceding the operation, preserving them in the small boxes in which they have been heated. It is possible that such an advance preparation might be permissible in case of operations of more special precision, as ovariotomies. But when greatly varying operations succeed one another in emergency, it would be impracticable to prearrange all the eventualities belonging to the instrumentarium a day in advance as we could have no knowledge of what we were to encounter under such circumstances. And if one of the carefully sterilized instruments that is indispensable happens to fall upon the floor and becomes con-

taminated, the method must still be abandoned for some other sterilizing procedure.

There have been numerous attempts made to shorten the unfortunately long duration of the hot-air method of sterilizing. It has been repeatedly endeavored to construct an apparatus which could be heated to a great intensity in a few minutes' time, and a temperature above 180° has been attained. It was believed that by 180° and upwards the duration of the sterilizing process might be shortened. These efforts have been thwarted however by the technical difficulties in attaining a uniform temperature where such a rapid and intense heating has been resorted to.

Even in the ordinary hot air sterilizer there are found to be sources of error in the often enormous variations of temperature which occur. We have had opportunity of making observations from the most reliable sources into this condition, and have been astonished at the enormity of the error. Variations of several hundred degrees between the temperature at the bottom and that at the top of the chamber is by no means rare.*

Such high temperatures and the very frequent heating to 150° or 180° change the molecular structure of the steel, transforming it into wrought iron and thereby depriving permanently the instruments of their temper and edge. The sterilization in hot air also rusts the instruments greatly, which is a point of much importance. We might infer that this would be impossible, as we have only to do with hot, dry

* This test may be made by introducing small plates of polished steel. The latter are placed in various positions in the sterilizer, and in a poorly constructed apparatus the steel will take on different colors. It will become gray and blue in the bottom, yellow in the middle, and in the top of the sterilizer, white. Here the surface thermometer scarcely registers 150° C. These great color variations in the polished steel represent at yellow 221° C. at blue 280°, and at gray 330°.

air, but nevertheless the instruments are often removed covered with rust, even though they were perfectly dry when put into the sterilizer. It appears that the cooling after such a rapid and intense heating favors the precipitation of moisture, although it may be possible, through good ventilation of the apparatus (Poupineal), to diminish the frequency of this objectionable occurrence.

For the reasons here enunciated we do not believe that the hot-air sterilization is of very great practical importance in the disinfection of the physician's instrumentarium. Quite different, however, is the verdict with reference to steam, which sterilizes in 12 to 15 minutes. The latter is used extensively for the disinfection of dressings, and often the surgeon has an apparatus of this kind at hand. Many who use steam for the sterilization of their instruments are really satisfied with it. However, extended experience will prove that this is rather an expedient than a method to be practised habitually. In steam the instruments also rust very easily. The nickeled instruments resist this fairly well, but those not nickeled usually become covered with a thick layer of rust and are rendered useless. The steam sterilization of the instruments occasions much inconvenience and requires a great length of time; its value is thus markedly impaired. Even though the instruments can be sterilized in live steam in 20 minutes, and, by proper construction of the apparatus and provision for a rapid working of the steam, the duration of the entire procedure reduced to 30 or 40 minutes, this for ordinary purposes is altogether too long.

Procedures which must constitute a part of the details immediately preparatory to operations can, when the latter succeed one another in very great numbers, not occupy a time much exceeding 15 minutes, without compromising the comfort of the physician and patient. The circumstances and

the expense involved in the construction and working of a steam sterilizer would render its use profitable only in certain operations. Accordingly the combination disinfection of the instruments with the dressings could be used only in lapa-rotomies and the major resections; in case of minor operations, which require properly the same aseptic precision, we would be inclined to resort to some other method. As in the hot-air disinfection, only just before the beginning of the operation is a steam sterilization of the instruments possible, and a necessary resterilization of an accidentally contaminated instrument, during the operation, cannot be executed with expediency.

The sterilizing power of live steam is greater than that of high-tension steam. It was first introduced for the sterilization of instruments by Redard (1889), and there has been constructed by him for the purpose a small autoclave, or self-regulating pot. The heating of this apparatus, according to Redard, required a quarter of an hour, and the entire sterilizing process, which occurred under a temperature of 110° C., is stated by him to occupy only forty-five minutes. The disinfection with this apparatus, properly constructed, may be very successful, but, as remarked at the beginning, the practitioner requires simpler methods. The manipulation of an autoclave with thermometer and manometer must be regarded as too complicated for the ordinary physician. Often only a slight error in heating the apparatus causes, instead of a higher tension, an overheating of the steam or of residual air, thus giving rise to a reduction of the sterilizing power. Then there is the objection that with this small autoclave in the hands of an unskilled attendant the graduated pressure limit is liable to be overreached ; the danger of an explosion is to be avoided only by one widely experienced in use of apparatus. For the disinfection of instruments we have the

same disadvantage here as in cases of the other steam sterilizers.

If from the foregoing practical deductions we have found it necessary to deviate from both the hot-air and steam sterilization of our instruments, we have remaining to consider the sterilization in boiling water and other boiling fluids.

A variety of solutions besides water has been suggested. Miquel, for instance (1880), advocated glycerine heated to 140°, C. and Tripier and Arloing in Lyons sterilize their instruments in hot oil. Redard observed that boiling glycerine disseminated an intolerable odor which precluded its use, and as for fat, it forms only too easily, as heretofore stated, an ensheathing and protective coating for micro-organisms. The oil sterilization requires an apparatus regulated at an exact temperature, and for this reason it is impracticable.

Quite different is the verdict with reference to boiling the instruments in water. Boiling water is an admirable disinfectant, surpassing even steam in rapidity and intensity, and can be provided readily.

It is a disputed question to whom belongs the credit of the authorship of the sterilization of instruments in boiling water. Individual practitioners used the method before there was any bacteriological science to clearly define its value. Undoubtedly we are indebted to Davidsohn, in a contribution from the Koch Laboratory, for first detailing and establishing scientifically the boiling-water sterilization of instruments. Davidsohn presented in a very distinctive manner the extreme value, of the method, and showed conclusively that a boiling of the instruments for five minutes usually sufficed for their disinfection. When steel instruments are boiled in ordinary water they rust, sometimes becoming covered with a thick layer, again showing only small black spots. The rusting always occurs if the instruments are laid simply in

cold water and then boiled ; if they are placed in water which has been heated to 100° C. for a time, they generally remain uninjured. It has for a long time been known, and was observed by Davidsohn, that the addition of alkalies to the water obviates this rusting. Accordingly a great variety of alkalies have been used—lime, chloride of sodium, caustic soda solution ; and by Redard chloride of calcium was found valuable. There is another alkali which for years has been used extensively in the von Bergmann Clinic for cleansing the instruments, and which since ancient times has played a very important rôle in domestic practice for general washing and cleansing; we refer to sal soda. A proportion of 1 per cent. of soda, as shown by the author, fully suffices to protect the steel instruments from rust. The addition of the soda does not vitiate the sterilizing force of the boiling water, as bacteriological investigation has proved ; on the contrary, the effect is enhanced by the addition, to the germ-destroying power of the boiling water, of the solvent and permeating action of the alkali. We may say that the boiling soda solution is the most powerful germicidal agent known to us which is applicable in practice. The author made frequent observations of the sterilizing effect by impregnating silk and also thick wool threads with pus and pure cultures of the staphylococcus pyogenes aureus, bacillus pyocyaneus, and anthrax spores, dipping them for varying intervals into the boiling soda solution.

Invariably it was found that the pus and also the staphylococci and bacillus pyocyaneus were destroyed in two or three seconds, while anthrax spores which, exposed to steam at 100° C., in some instances after twelve minutes, had still remained alive, and were consequently extremely resistent, were destroyed absolutely in two minutes by the boiling soda. A submersion of the instruments for a few seconds would therefore be sufficient to destroy the contained pus formers,

and a boiling for five minutes in the soda lye answers every possible requirement of practice. The great disinfecting value of hot-soda solution was confirmed by extended investigations made by Behring with sal soda lye used for general washing purposes. The soda lye is employed in the latter instance usually at a temperature of 80° to 85° C., and Behring found by bacteriological tests, greatly to his surprise, that even thus far below the boiling point the disinfecting power of the lye is enormous. The most resisting anthrax spores were destroyed often in four, positively in eight to ten minutes in soda solution at 85° C. It is further of interest to know that, according to Behring's investigations, the washing lye as commonly used contains about 1.4 per cent. of soda, a proportion therefore closely corresponding with that recommended by the author as necessary for the sterilization of instruments. The fact of the hot soda being so extensively used in the washing of clothing and for many other cleansing purposes in households—the dissolution and removal of fat and dirt—is suggestive of its peculiar adaptability to the sterilization of the surgeon's instruments. It should be generally adopted by reason of its combined cleansing and disinfecting power.

The rapidity and certainty of its germicidal action is not the only advantage of the soda sterilization. Of much importance is the simplicity of the method and the absence of the necessity of skill in its technique. If there is any procedure capable of becoming improvisional in the physician's practice it is this. For the sterilization of his instruments all the surgeon requires is some water, fire, a pan or basin, and some soda—all of which are to be found in every house. For a change of dressing at a patient's residence it is more rational to dip the few instruments needed—the scissors, forceps, etc.—into a basin of hot water and soda for a

few minutes, than into the more expensive carbolic acid obtained from the apothecary. In regard to the disinfection, much more is attained. Even in large operations this method may be used. The instruments are laid in a clean cooking vessel and water (warm if possible) is poured over in quantities sufficient to submerge them, then about a teaspoonful of pulverized soda to the litre of water is thrown in and the vessel placed upon the fire. In a few minutes—the interval of the remaining preparations,—the instruments have been heated sufficiently; the vessel with its contents is then cooled by setting it into a pan of cold water, after which, during the operation, with a feeling of certainty as to their being sterilized, the instruments are used.

When one has become accustomed to the soda sterilization of instruments and uses it extensively, this simple cooking vessel soon fails to answer the requirements, and we realize the necessity of an apparatus which affords greater convenience.

The following device, illustrated by Fig. 4, is used in the large operating room of the von Bergmann Clinic and has reached its present state of perfection after repeated trials and modifications by the author.

The first provision in its construction is the possibility of rapid heating. The bottom is therefore corrugated to increase the extent of surface and for utilizing fully the heat generated, the apparatus is enveloped in a mantle. Heat is provided through a long gas burner with many cross-arms, or by alcohol in one large or several small flames. The boiler is closed by a tight cover. Koch has demonstrated (*Mittheilungen aus dem Kaiserlichen Gesundheitsamt*, Bd. i.) that a quantity of water boiling in an open vessel has not always a uniform temperature. There are found variations of many degrees in the upper and lower strata.

In order to obviate this, a tight-fitting cover is indispensable. The 1 per cent. solution, boiling in a perfectly closed tank, has a temperature of 104° C. If the cover be raised and the boiling continued, the temperature at once drops to 95° or 93° C. upon the surface. It is of particular advantage, in case of a large apparatus, to have a cover with a water seal, because

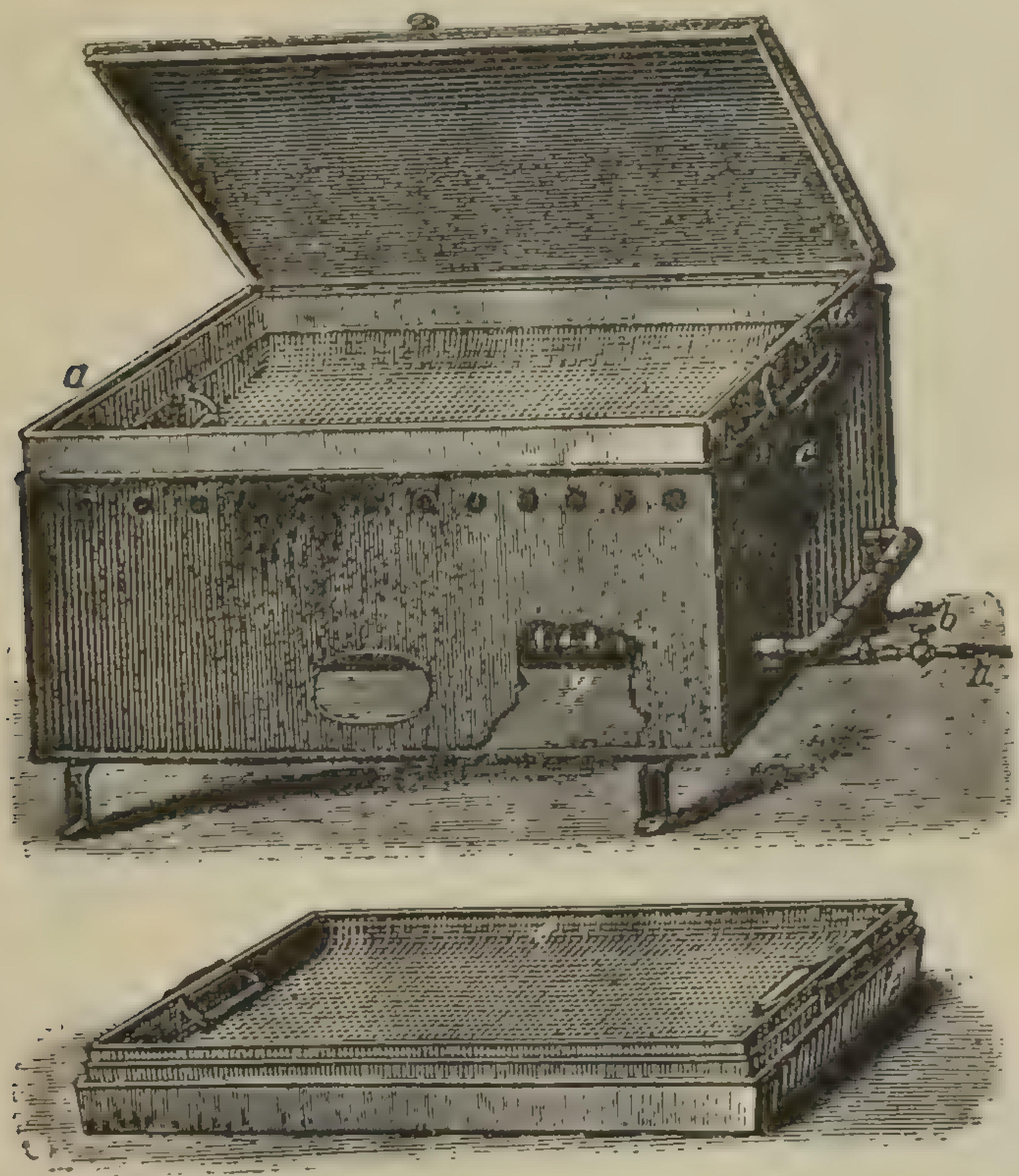

FIG. 4.
SODA STERILIZER FOR INSTRUMENTS (SCHIMMELBUSCH).

this secures the most perfect closure and seems to limit the evaporation of the soda, a thing which is worthy of effort for avoidance of the over frequent filling of the apparatus necessary in its continued use. Pursuant to the same object, the gas jet is provided with a stop-cock adjustable in three directions. These changes of position admit of the flame being very large, entirely cut off, or of being made to burn very

low, giving in the first instance enough heat to cause active boiling and in the last allowing just sufficient to keep the solution warm. A properly constructed apparatus should insure water of room temperature being boiled in five to six minutes. By heating with gas supplied through a pipe of proper size, and under sufficient pressure, this is readily accomplished; less easily by alcohol, however. In using a powerful spirit flame it is difficult to avoid the danger of an explosion, unless we resort to a complicated contrivance. Here, as in case of the old oil lamp, the supply receptacle must be placed to one side, then the alcohol will not be overheated. But where the use of the spirit flame is necessary, as in private practice, an intense degree of heating is not required, and a small lamp will answer the purpose if the vessel be filled with warm water, which is usually obtainable, at the beginning.

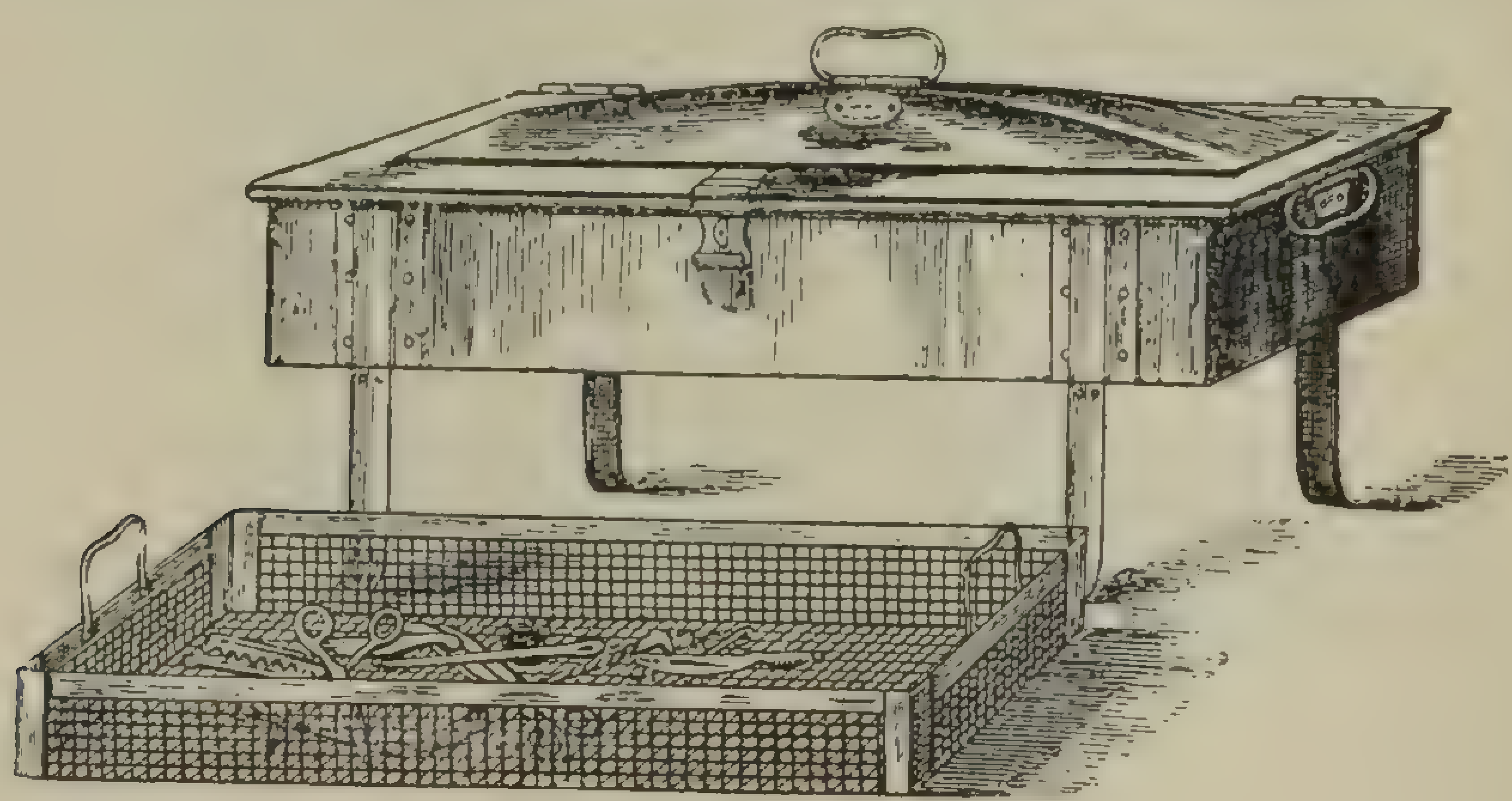

FIG. 5.
TRANSPORTABLE STERILIZER FOR INSTRUMENTS (OPEN).
(It may be placed upon the stove or heated by means of a spirit lamp.)

Figures 5 and 6 represent a sterilizer designed for private use in which dressings can also be asepticized. (See chapt. vii.) The apparatus, which may be made by any tinsmith, consists of a quadrangular box with a clasped cover that has a water seal. The dimensions are: depth, 10 to 12 cm.; width,

15 to 20 cm., and length, 20 to 40 cm. according to the size of the instruments which the operator uses. Upon the sides of the box are four grooved strips into which legs can be introduced. In this box the instruments and spirit flame may be transported. For use in sterilizing it is filled with hot water, to which a spoonful of soda is added. It is then set directly over the fire, or the water is boiled by means of the alcohol lamp. In the latter instance the box is raised upon legs, as above indicated. The flat Berzelius lamp is preferred in using alcohol.

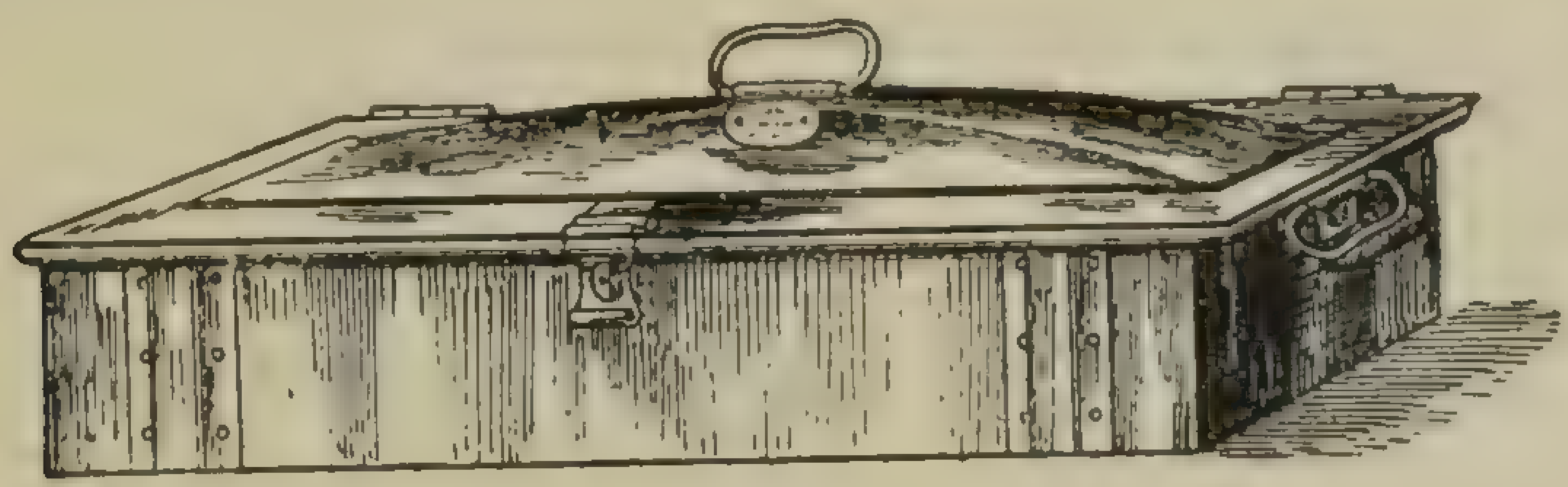

FIG. 6.

TRANSPORTABLE STERILIZER FOR INSTRUMENTS (CLOSED).

In order to facilitate the laying in and removal of the instruments from the soda solution, a simple wire tray is added.

The smaller instruments, after sterilizing for five minutes in the soda solution, cool rapidly in the air upon removal and are ready for use. The larger instruments, as the heavy forceps and chisels, require a longer time, and it becomes desirable to hasten the cooling.

For this reason, and also because it is agreeable, the instruments are kept in a solution during the operation; the wire baskets in which they had been laid while sterilizing being placed in a tray, such as was formerly employed for submerging the instruments in carbolic acid. These trays should be slightly smaller than the sterilizer, so they may be placed in the latter and asepticized. The soda solution, which has been boiled, may be used for filling the tray, or any antiseptic

may be employed, as alcohol or carbolic acid. The instruments should not be submerged in pure carbolic acid, as this causes them to rust. Very efficacious is a mixture of carbolic acid and soda—carbolate of sodium,—and it is recommended that a solution containing 1 per cent. each of carbolic acid and soda be used.

It is unnecessary to submerge the instruments in a strong antiseptic, as they are already sterile.

This apparatus is made preferably of copper or nickel. Sheet iron is inapplicable. Too large proportions in the construction should be avoided, as the manipulation is thereby rendered difficult. The boiler does not require to be more than 10 cm. in depth, the length and width for use in a very extensive practice may be 45 by 30 cm.; medium size, 45 by 20; small size, 25 by 15.

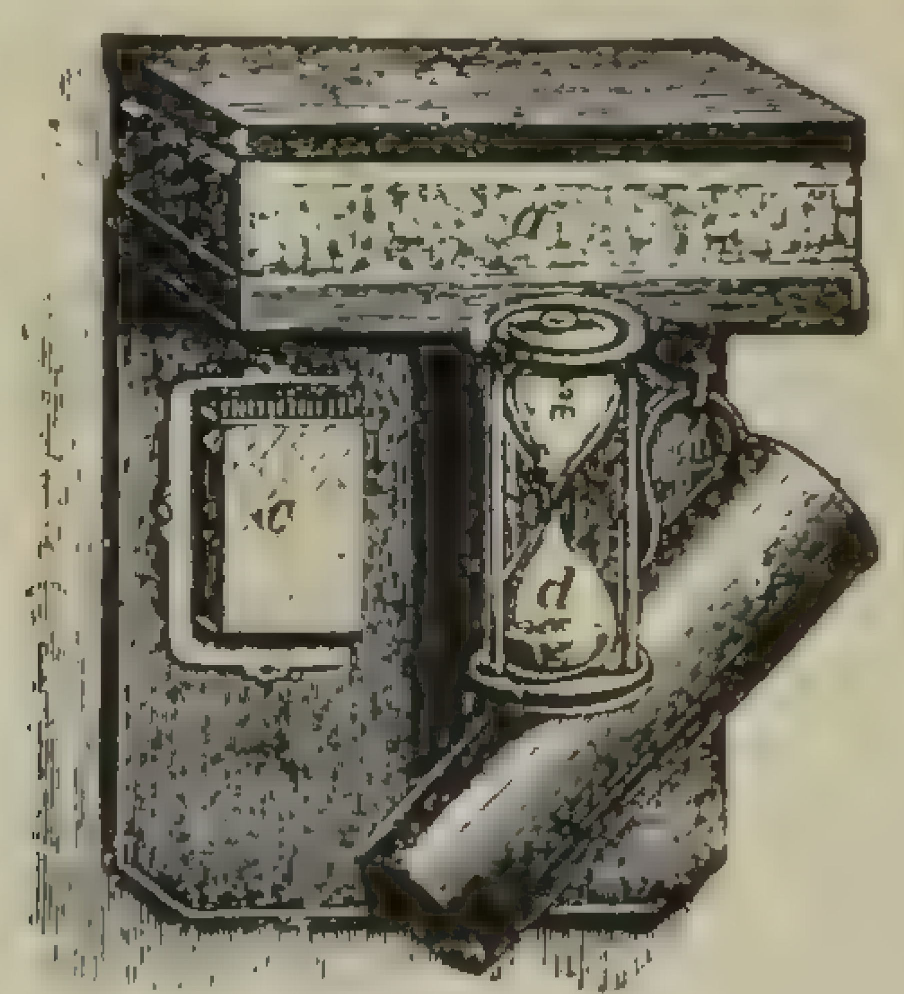

FIG. 7.

SODA RECEPTACLE, WITH HOURGLASS AND MEASURE, BELONGING TO THE STERILIZER FOR INSTRUMENTS.

It is advantageous in a clinic to prepare the soda solution in advance. The solution in which the instruments are boiled, and that used in private practice, may be made as required. To facilitate matters, we have designed a receiver for pulverized soda, in which is placed a scoop that contains exactly 10 cb. cm.; one measure is added to each litre of

water in the sterilizer. A very neat combination of the utensils belonging to the soda sterilizer is shown in Fig. 7. The box (*a*) containing the pulverized soda, in which is placed the scoop, rests upon a small bracket. Underneath is a litre measure (*b*), and a match box (*c*), and in front is a five-minute hour-glass (*a*). There has also been devised a soda tablet, the number to be added being determined by the size of the apparatus.

Of all the disinfecting procedures, the soda sterilization damages the instruments least. Even the knives may be boiled without becoming dull, as determined by recent investigations, if precaution be taken to prevent their motion to and fro in the soda. The reason why the knives lose their edge seems to be the fact of their being tossed against one another by the fluid as it becomes agitated in boiling. These and all other cutting instruments must, therefore, be wrapped or placed in a firm frame.

The directions for sterilizing the instruments according to the principles here enunciated may be formulated as follows:

1. The instruments are laid in a wire basket, and shortly before the operation they are boiled for five minutes in a 1 % soda solution. Knives are rubbed with alcohol and sterile gauze, and can only be dipped into the boiling soda for a few seconds.

2. The instruments are taken out of the soda solution in the wire basket, and set into a tray. This tray is also sterilized in the alkali and filled, preferably with boiled soda solution, or carbolate of sodium.

3. During the operation, instruments which have become contaminated and are needed for further use are douched with cold water and re-dipped into the boiling soda.

4. After use, the instruments are washed with cold water, and laid in a hot lye of soda and soft soap for several hours.

They are then brushed and dried carefully with alcohol and chamois.

Most of our older instruments are not able to tolerate this rigid cleansing, and the application of moist heat. Wood, horn, and caoutchouc handles on knives, curettes, etc., formerly so popular, are too perishable, and the modern instrument manufacturers have substituted for them metal handles. It is a matter of habit whether an individual operates with a light horn or a heavy metal-handled instrument with the greater ease; acceptability must be made subservient to utility.

If we are necessitated to use an instrumentarium of ancient manufacture, it is always important to know that the instruments with wood and horn handles may be boiled a number of times, if the handles are riveted on and not simply cemented or glued. Only too frequent or daily boiling damages them.

All scrolling, decorating, Æsculapian meandering, and the popular lion-head carving, formerly so pleasing to the eyes of the physician, are naturally rejected by the modern asepticer, and every effort of the instrument manufacturer to construct in simplicity the surgeon's operative outfit so as to facilitate cleansing, should meet with approval and support.

The nickel-plating of instruments has not the importance which we have been accustomed to attribute to it. This is, however, a means of preventing the troublesome rusting, resulting from submersion in carbolic acid, sterilization in steam or hot air, but with instruments much used the plating only lasts for a short time. It requires frequent renewal and each additional plating holds less firmly; the coating persists in chipping off, and finally the instrument becomes absolutely worthless. The nickeling, or better still the silver-plating, answers for utensils that are little used and preserved for

special occasions. They are thus protected from atmospheric influences. The instruments used daily no longer require to be plated, as we have learned that the soda sterilization prevents all rusting ; they are made preferably of plain material with smooth finish. To avoid rusting after being put away in cases or boxes, however, the instruments must be very cautiously

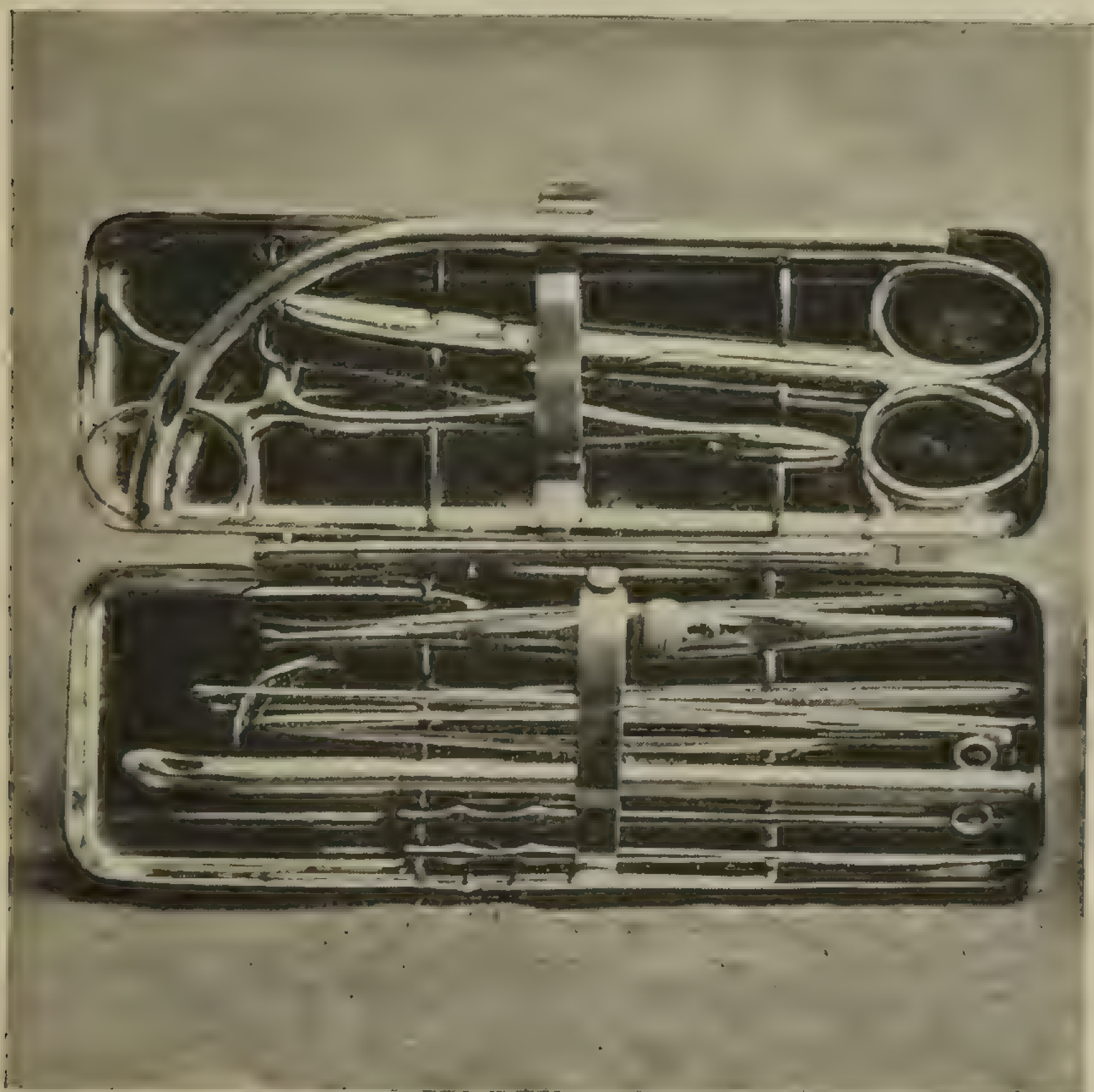

FIG. 8.

ASEPTIC POCKET INSTRUMENT CASE (THORNBURY).

dried. The attendants require close watching to insure this being done. Instruments once rusted always have a tendency to return to this condition, even after they have been thoroughly polished. According to repeated investigations by us, instruments made of aluminium are worthless. The metal is too soft, and to the trials of disinfection it is even

less resistent than horn and wood. The soda and strong lyes gradually dissolve it away. A small instrument made of aluminium lost, in one of our experiments, one ninth of its weight by boiling for five minutes in a 1 % soda solution.

The case or cupboard for instruments should be constructed so that it can be conveniently cleansed. Glass and iron are best for the case proper ; metal plate may be used for the trays. The instruments contained in the trays, on metal bars or on intervening layers of sterilized cotton, rest in the case on glass shelves. The pasteboard and leather boxes, with a lined common compartment for instruments, and also those separated by leather pockets, belong to times gone by. The rolls made cheaply from canvas may still find a place in permitting of being sterilized in steam.

The following is an aseptic pocket instrument case designed by the translator :

The instruments which it contains are these :

One pair curved or flat scissors, French lock.

One pair Pean's artery forceps, French lock.

One Dr. Roswell Park needle holder and artery forceps combined.

One pair thumb forceps.

Two scalpels.

One male and female combination catheter.

One director and aneurism needle.

One small probe.

One groove director.

The case with its contents may be sterilized by setting it into a basin of water to which is added a small quantity of soda, the basin being then placed upon the stove.

The instruments with their clasped trays may also be sterilized in the boiling alkali separately. The knives must not be allowed to remain longer than fifteen or twenty seconds.

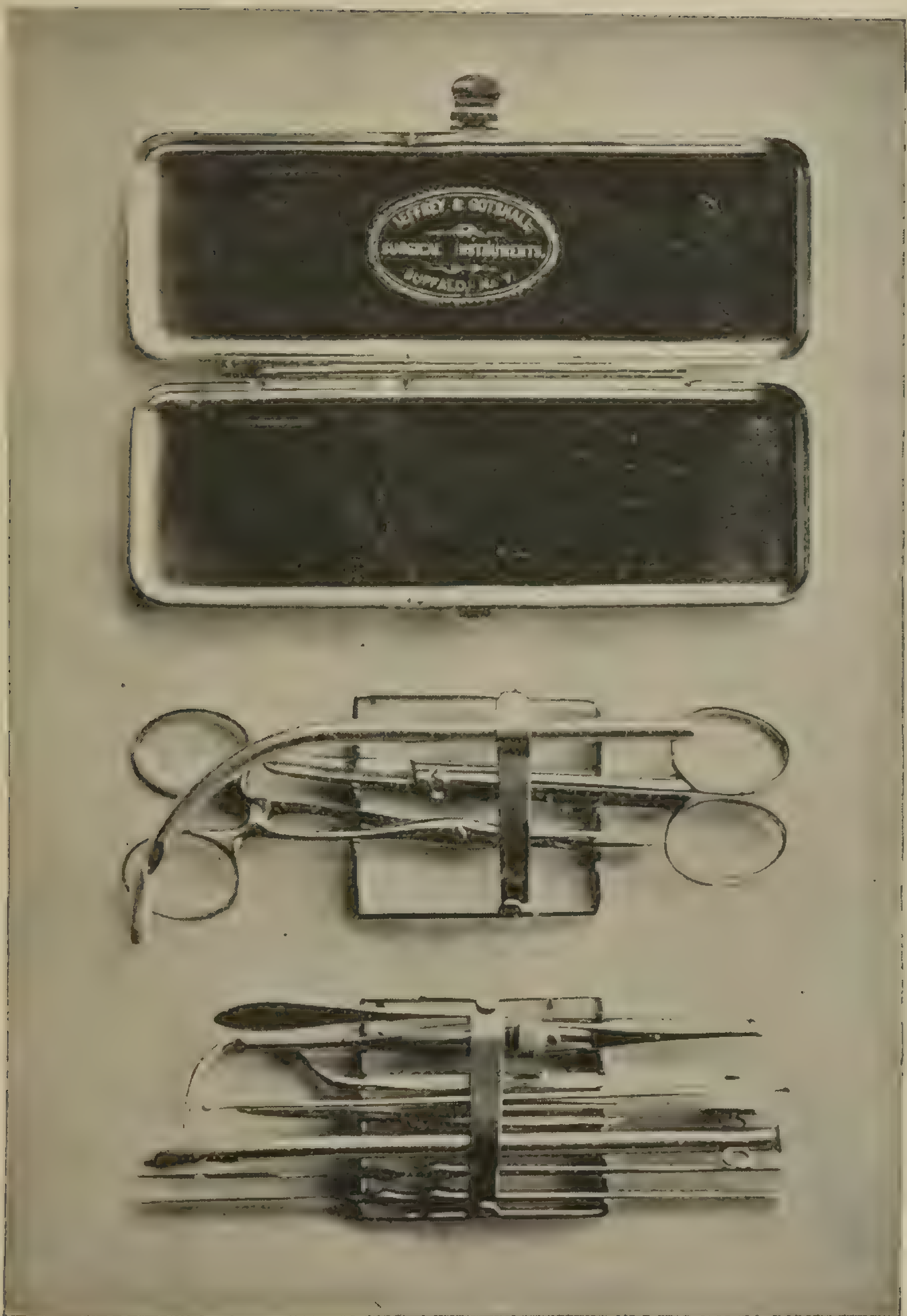

FIG. 9.

ASEPTIC CASE (THORNBURY) WITH TRAYS AND THEIR CONTENTS REMOVED.

This case will be found very convenient and is superior to the ordinary leather pocket cases on account of its greater safety and the facility with which its contents—the instruments most commonly used—can be sterilized. Contamination of the instruments within the case is obviated by the latter being itself aseptic.

CHAPTER VII.

ASEPTIC DRESSING MATERIALS.

Open Treatment of Wounds—Absolutely Tight and Impermeable Closure—Importance of the Capability of Absorption in Dressings—The Various Materials Employed—Their Efficiency—Dressings must be Free from Bacteria—Disadvantage of the Disinfection of Dressings by Means of Chemical Agents—Sterilization in Steam—Advantage of the Same—Sterilization of Dressings for the Requirements of the General Practitioner and for Hospitals—Principle of the Closable Dressing Receptacle—Antiseptic Property of Dressings—Importance of the Drying out of the Wound Secretions—The Working of Dressings Impregnated with Antiseptics—Superiority of the Simple Dry Sterile Dressing—Wound Tampons—Iodoform Gauze—Pre-Excellence of Self-Prepared Dressing Materials—Reliable Factory Dressings are not entirely to be Dispensed with.

We know from experience that a wound may be exposed for hours during an operation to the action of the air, if the latter be free from dust, without entailing any special danger of infection. And yet we would not be justified in returning to the so-called open method of treatment ; for the stirring up of dust and dirt about the patient is sure to take place soon, and the danger of infection cannot long be obviated. The open method of wound treatment, introduced into practice in the pre-antiseptic period by Kern, was attended by more favorable results than all methods previously used. Burow, who, like most operators, lost one half his patients upon whom amputation was performed, had a series of ninety-four cases treated by the open method, *i. e.*, without any dressing, which gave a mortality of only 7.5 per cent. It must have been better not to have covered the wound at all, than to have used the material

then in vogue, rich in infectious micro-organisms, even though during the slow recovery the wound often became contaminated to an alarming extent with dust, dirt, and even maggots. To-day we can, through aseptic dressing, avoid to a certainty the dangers of infection to which a wound is exposed after an operation. Only perhaps in one instance is it justifiable to omit this regular dressing, namely in superficial cutaneous wounds where nature, by drying the secretions, forms a crust and provides thus a protective covering. The experiments of constantly irrigating wounds with solutions, or of keeping them submerged continually in a water bath during the entire process of repair, are only of historic interest. Both cause irritation, macerate the integument, and are to be denounced on grounds of asepsis. If stronger germicidal agents are used for the bath and irrigating fluid, there is danger of poisoning the patient by absorption of the material from the wound, or through the eczematous skin of the patient ; if weak solutions are employed, we do not prevent the development of infectious micro-organisms.

The present requirements of an antiseptic dressing are essentially three. The dressing must :

1. Absorb well the wound secretions,

2. Be free from pathogenic organisms,

3. Work antiseptically, i. e., prevent decomposition of the absorbed secretions.

A priori it may appear as the better method of protecting wounds against pending external dangers to close them tightly. The complete and firm closure was also one of Lister's ideas. The dressing which he applied originally consisted of a cement of prepared chalk and linseed oil, such as is used by glaziers. To this was added only carbolic acid. The whole mass was then laid over the wound and covered by a tin plate. At the present time the sealing of wounds has a certain province in

surgical practice. In fresh wounds of the soft parts, with edges evenly approximated, and in which by means of sutures the margins throughout their entire extent and depth can be held together, as in superficial cuts and sabre-wounds of the face, this simple method may be utilized. We may agglutinate the edges along the suture line with some non-irritating plaster, collodion, or, better, photoxylin, which is more elastic and does not compress the margins so much. The latter may be pencilled upon the wound directly or applied over an intervening strip of gauze. These applications are preferable to the glazier's putty mixture of casein and salicylate of potash or to tinfoil. The instances in which healing occurs under a scab belong to this same category, also those in which the repair takes place under a crust formed by the rapidly dried blood. The plastering or agglutination with photoxylin has simply the advantage of affording an artificial covering that holds more firmly than the natural scab or crust, which only falls off under slight insult. But this method of treating wounds has always held a very limited range of usage, its success being dependent on a single condition. Practically no discharge is permitted, and as the wound absorbs only a small quantity of fluid the agglutination must be illusive,—even dangerous. The discharge, by which we understand the oozed blood, the lymph and delayed transudation, stagnates under the impermeable coating and forces itself in one direction or another, breaking through at the point of least resistance, then simply undergoing decomposition. This places the wound in a worse condition than if it had not been dressed at all. In order to protect a secreting wound (and most wounds are of this nature) by a dressing, this dressing must be able to take into itself thoroughly and completely the products which the wound offers.

Lister very early recognized this fact, and selected a mate-

rial which has ever, up to the present time, remained a preferred article for dressing, viz., absorbent gauze.

The question of expense is the only objection which can be raised against its use. Many attempts have been made to replace this by other articles, and proposals continue to be advanced, yet these are only expressions of an endeavor to find a cheaper, rather than a better material. All the articles which have been suggested to replace gauze, from filter paper to moss, and from here down to ashes, sand, and earth, are much inferior in efficiency. For the direct covering and tamponing of wounds gauze is indispensable; being a fabric it is coherent, and leaves no particles behind to irritate the wound and retard the healing process. All powdered materials which have been recommended for dressings have this detrimental quality in a marked degree. Cotton, which is quite universally serviceable and popular, is not adapted for direct application to wounds. With its use the dressing becomes dry, packed, and adherent, and can be removed only with difficulty. All powdered and non-coherent materials are to be excluded, except when they are enveloped in gauze and sewed into small wads or pads. It is difficult to determine, by means of theoretical calculation and experiments, the value of a dressing material and its power of absorption, such a variety of factors come into question. It is more reliable to decide from practice—*i. e.*, by observation of the effect upon wounds. A high absorptive power for fluids is not in itself determinative of the value of a dressing material. Neuber, Fehleisen, Walther, and Rönnberg, have estimated the absorptive potency of various articles by allowing ten grammes of each to absorb moisture to its maximum capacity. The materials were then weighed, and Rönnberg sketched the following table as the result of his experiments. Ten grammes of each material weigh, saturated:

1.	Deoleated cotton	250.0
2.	Plain absorbent cotton	230.0
3.	Wood cotton	150.0
4.	Wood wool	106.0
5.	Gauze	96.0
6.	Bog moss	82.0
7.	Poplar sawdust	73.0
8.	Jute	70.0
9.	Pine sawdust	53.0
10.	Coal ashes	21.0

According to Neuber, cotton is capable of absorbing about three times, according to Fehleisen, one half to double, as much water as gauze. In the Rönnberg table cotton will also be found at the head, yet practical experience teaches us that it is not nearly as efficient in disposing of the wound secretions as gauze. The quality of an article to be used for dressing should not be measured by the quantity of fluid which it will absorb on mere contact. This has been investigated by placing a variety of articles in vertical glass cylinders dipped into water or blood, and equally compressing them by means of small weights. The fluid ascends to varying heights in the different articles, and indicates their respective absorbing powers. Rönnberg found that materials thus placed in cylinders of 4.5 cm. diameter, under five hundred grammes' pressure, absorb water to the following varying heights:

LEVEL OF THE ABSORBED FLUID.

Coal ashes	6.4 cm.
Absorbent cotton	4.6 "
Bog moss, moistened	4.0 "
Sawdust	4.0 "
Wood cotton	3.6 "
Lint	3.3 "
Common cotton	2.9 "
Sea sand	2.7 "
Pulverized asbestos	2.7 "

Absorption in this manner was found to be almost *nil* in case

of jute, oakum, dry turf, and cut straw. It is evident that the materials which are most efficacious according to the appended table are quite inapplicable for dressings. Experiments which determine the quantity of fluid that the various materials can absorb in equal successive periods, and then allow to evaporate, would afford much more decisive data. The dressing must not take up its maximum quantity of fluid at one time, but rather absorb continuously and dry out promptly by evaporation. Most materials which absorb quickly and excessively large quantities of fluid, as blotting paper, silk-lint and absorbent cotton are entirely inadequate for dressings, because after they are once filled with fluid the capability of further absorption is lost. They become soft and packed and form an almost impermeable layer, similar to pasteboard. There are many other important points which come into question besides the rapidity of absorption (important in materials used for sponging), as the change in volume while saturation is taking place, the change in elasticity, etc. If we recapitulate the teachings of the numerous practical experiments of the past decade, we find that, next to gauze, moss has proved itself to be the better dressing material. It does not matter whether we use bog moss or wood moss; for dressing purposes it is washed clean and dried, and is then either sewed into small pads or else used in form of the so called moss felt (Leisrink), which is made by compressing the material in its moist state. Moss is very cheap, soft, pliable, and absorbs readily. As a padding material it is also to be recommended by reason of its elasticity, so it surpasess even cotton in its efficiency. Still we hesitate in deviating from the use of the latter in dressings, notwithstanding its limited power of absorption. Cotton possesses the virtue of special softness and pliability, besides being so simple and easy of application.

Next to moss and absorbent cotton, the most practical dress-

ing materials are those made of wood—wood fibre, wood wool (shavings), and sawdust. Their absorptive power, however, is much inferior to that of moss. Peat gauze, among the powdered forms of dressing, by virtue of its great absorbing power, is very excellent. The numerous other articles that have been tried, as sand, ashes, tan bark, oakum, bran, finely cut straw, etc., scarcely come into consideration now under ordinary circumstances. Only in cases of necessity, as in war practice, are they likely to be employed.

The most important requirement of aseptic surgery, as regards dressings, is, that the material used be free from pathogenic bacteria. After the elucidations of the foregoing chapters it would hardly seem necessary to lay special stress upon this requirement, unless cognizance of the advantageous working of absorption and the efficiency of evaporation did not give rise to the deduction that by reason of these influences the necessity of asepsis is superfluous. The effectual removal of secretions from the surface of the wound is most important, and in a measure a pre-requisite in dressings. The freedom of the material from bacteria, however, is as essential as a component element is indispensable to the whole—an integrant in affinity with integrant—the chain connecting the whole aseptic method of treatment. As expressed by Volkmann, the human organism is not exactly a test-tube filled with agar-agar or coagulated blood serum, and the contact with infectious materials does not inevitably lead to infection.

The determining factors, though not yet fully elucidated, pertain to the animal organism and vegetable microbes. There are bacteria, as the erysipelas streptococcus, which infect the human body through the smallest and most superficial wound—the inoculation stick—quite as certainly as gelatin and blood serum are inoculated in the tube. Neglect of the scrupulous disinfection of the dressing materials may not lead

to bad results, but usually is dangerous or even disastrous. Therefore the fundamental law must be that all materials which are to encounter the wound directly and absorb its secretions shall be free from pathogenic organisms. We have differences of opinion as to the necessity for asepsis in padding and splinting materials, but here the rule must be not to sacrifice safety for convenience. In the treatment of recent compound fractures and of cases complicated by phlegmon, it is positively hazardous to employ the old splints used in a hospital without disinfecting them. In the von Bergmann Clinic pasteboard and sawdust are employed for splinting by preference, and then destroyed in conformance with the principles of asepsis. For dressing, materials should be obtained which are free from bacteria at the beginning and which are readily sterilizable. Hence the suggestion of Hewson to use earth, which usually contains tetanus spores, is very irrational. We have already made a great advance as we have now at our disposal factory prepared dressing materials, and are not dependent upon domestic industry or convict labor—the former sources of our lint. Raw materials supplied by factories contain fewer bacteria than unravelled linen prepared in such an uncleanly manner, having been subjected to a hundred-fold contact of hands. Up to the present time the popular method of preparing dressings was to disinfect them by saturation with an antiseptic solution after a preparatory cleansing. This was undertaken with at wofold purpose—first, that of asepticizing the dressings ; second, that of imparting to them an antiseptic property. Of the latter we will treat later ; here we wish to emphasize, that a condition of asepsis, through simple saturation with antiseptics, cannot be attained to the degree of certainty that has been supposed. The action of disinfecting solutions must continue for a long time, often for days, in order to destroy resistant spores, and this effect may be en-

tirely wanting when there are present impermeable layers of fat and albuminous substances which envelop the bacteria.

By careful preliminary cleansing and long-continued saturation with strong antiseptics, this possibly may be obviated. A still greater objection against the preparation of dressings by impregnation, is that the asepsis, perhaps present at the beginning, is placed in question by the subsequent manipulations in pressing, cutting, drying, and packing the materials. It is a serious disadvantage to have the disinfection constitute the end instead of the beginning of the process, and to have the impregnated and sterilized dressings pass through the hands of a dozen different persons engaged in their preparation before the work is completed. Were those individuals under the scrutiny of a physician, the method might be successful, but it is not possible where, as in the majority of dressing manufactories, other than medical requirements govern the work, and the understanding for the manipulation fails with the managers. This method of preparation explains why Schlange, and after him others who examined bacteriologically impregnated factory prepared dressing materials from various apothecary shops, found them to be rich in bacteria. Also why only those prepared in the army under control (Löffler) revealed the absence of germs. After factory dressings reach the physician their manipulation begins anew. The packages are opened, the dressings spread out, properly cut, and re-packed in boxes. We can understand that materials so prepared have been subjected to a series of dangers to infection before being applied to the wound. By sterilization with heat, especially in the form of steam, positive asepticism and the avoidance of all sources of error may be accomplished. Hot air is inapplicable, as it damages the dressings and causes them to become brittle. Hot water is excluded, because the articles must be dry for use and preservation.

Not alone upon the fact that the freeing from pathogenic organisms is attained with absolute certainty and in a very short time does the superiority of the steam sterilization as compared with the impregnation with antiseptic agents depend, but still more upon the readiness of the application and the advantage that the sterilization may be executed frequently, when necessary, daily, or shortly before the operation. The dressings may be sterilized in that condition in which they are applied directly to the patient and in the same receptacles from which they are taken, so that all manipulations after the disinfection, excepting those unavoidable during the operation, are obviated. The articles are prepared just as they are required for use ; the bandages are rolled, the cotton cut, and the gauze arranged in lengths. The whole is then put into a receptacle, preferably of tin, which can be closed, although the dressings are sterilized with orifices in the boxes open. After the sterilization is completed the movable bands are slid over the orifices in the receptacle and the materials are thus completely protected. This principle of the closable receptacle we regard as very important. The method is decidedly more reliable than the packing of the dressings in closets or other non-sterilizable receivers.

Regarding the application of steam, whether it is to be applied in an expanded, super-heated, or circulating condition, we have finally come to the conclusion that simple live steam for the sterilization of dressings, as well as for the general requirements of the practitioner, answers fully. Dressings sterilized in steam have been used in the von Bergmann Clinic for over eight years with the most satisfactory results. One requirement must be conformed with, however, in order to secure sufficient action of the steam, *i. e.*, the latter must be "saturated." All air must be removed from the sterilizing articles and provision made for the rapid entrance of the

disinfecting agent. From this we can understand how irrational it is to steam dressings in open vessels. It is necessary that the articles be placed in a closed and separated compartment (the sterilizing chamber), which the steam enters, to expel the air completely. For limited use the old steam sterilizer designed by Koch answers all purposes. This apparatus consists of a cylindrical sheet-iron chamber in the lower part of which there is space for several liters of water. A few inches above the water's level, there is a lattice-work, which forms the floor of the sterilizing chamber ; the apparatus is closed at the top by a tight cover. When the water boils in the reservoir, the steam ascends through the wire bottom into the upper chamber, encounters the articles, expels the air present, and escapes with light pressure under the cover at the top. If the apparatus is of the proper dimensions, and the production of steam active, the air is entirely displaced and condensation is avoided.

But if the dressings are allowed to remain cold, when heat is applied to the sterilizer they become saturated through condensation of the steam, so that in using the Koch apparatus a special device for previously warming, or an arrangement for subsequently drying, the dressings is necessary.

Many attempts have been made to construct on the principle of the Koch sterilizer a small apparatus which would be adapted to the requirements of the general practitioner. Such an apparatus can only succeed which works rapidly, develops a high pressure of steam, and is readily transportable. Furthermore, the principle of the closable dressing receptacles must be utilized. The necessity for an apparatus of this kind to provide for the associated soda sterilization of metal instruments is obvious.

We will not attempt to consider the various similar devices of Rotter, Straub, Braatz, Mehler, Kronacher, and others, as we have not had sufficient

experience in their use. The author has found the following sterilizer of practical value. It has been modified in the course of years of usage to conform to its present simple construction.

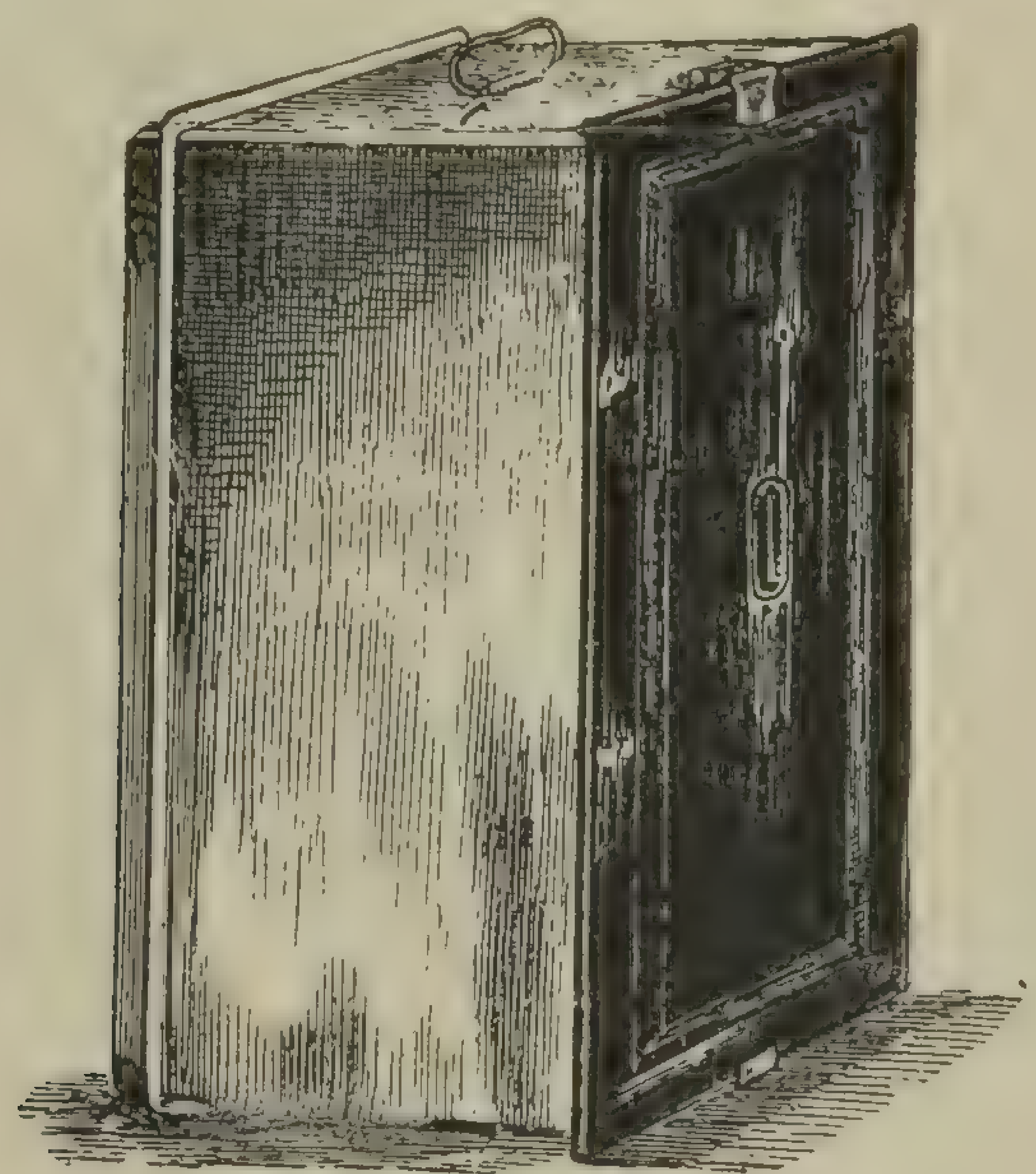

FIG. 10.

UPRIGHT PART OF DRESSING STERILIZER.

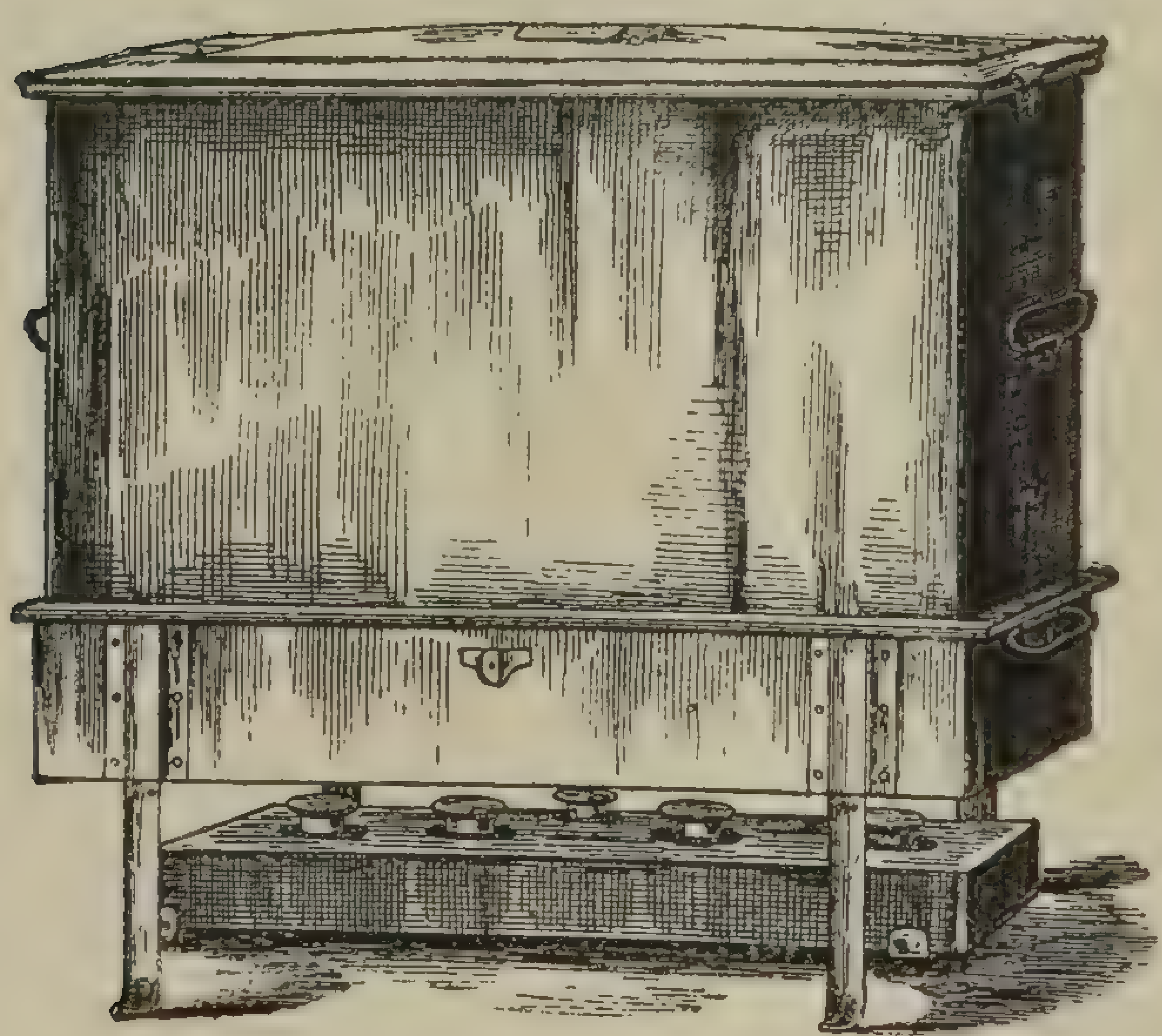

FIG. 11.

COMBINATION STERILIZER FOR DRESSINGS AND INSTRUMENTS.

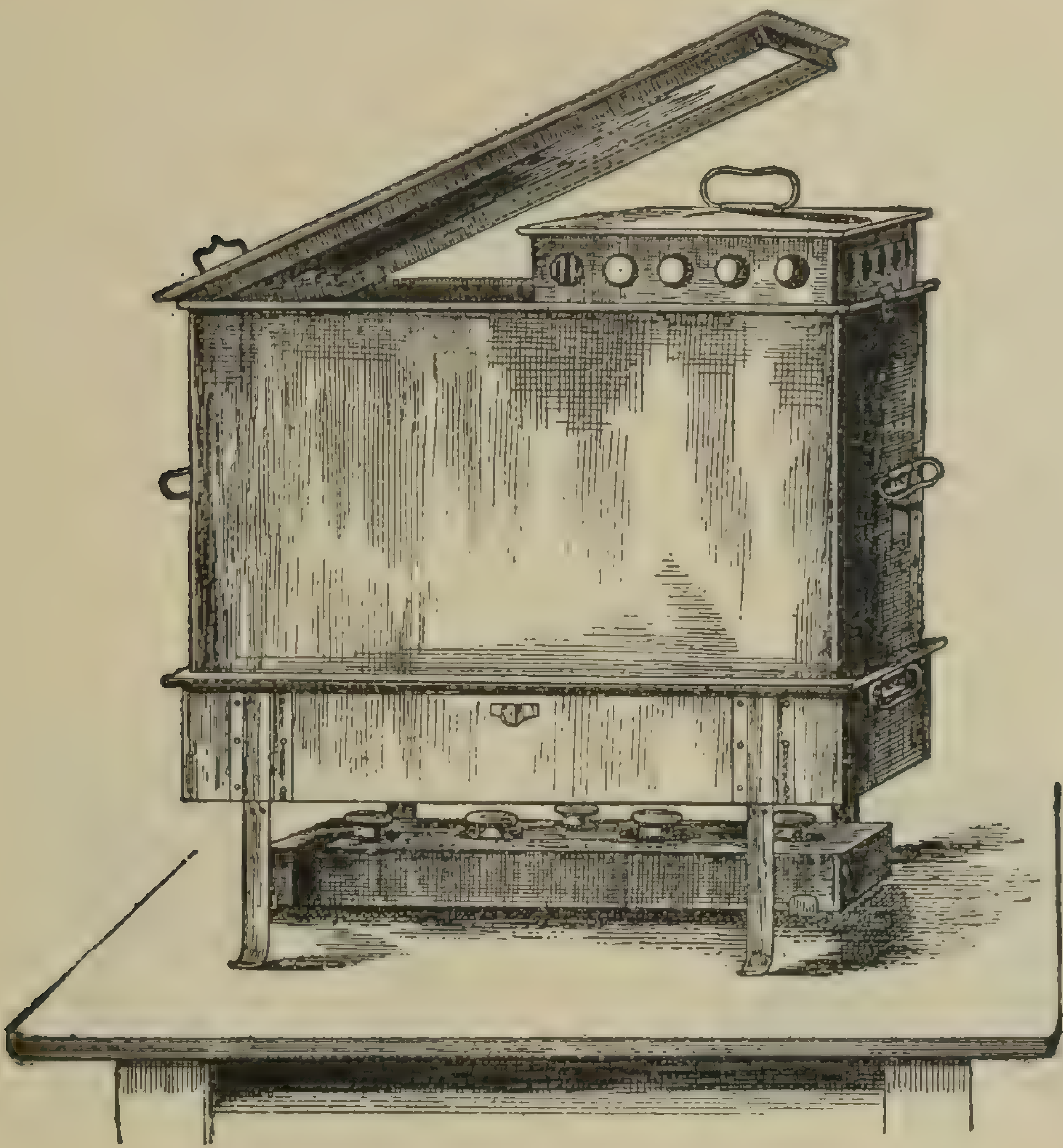

FIG. 12.

DRESSING STERILIZER—STEAM CHAMBER OPEN, SHOWING SUB-COMPARTMENT.

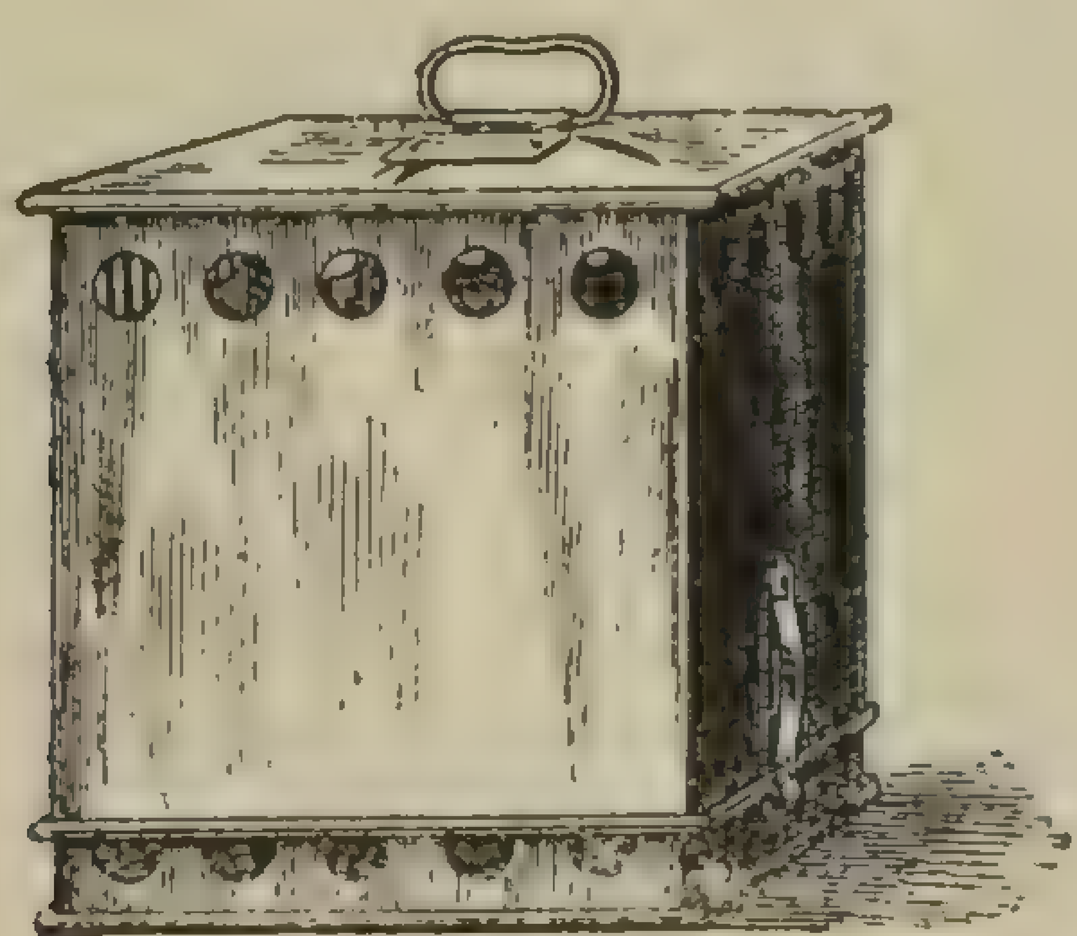

FIG. 13.

DRESSING BOX, OPEN.

The lower portion of the apparatus—that which is used for the sterilization of metal instruments, is the same as is described in the foregoing chap-

ter. It is provided with a water seal, into which, after the cover is raised (Fig. 11), an upper oblong part is set. This (Fig. 10) serves as a receptacle for the dressings to be sterilized. Within it may be placed closable boxes or sub-compartments (Fig. 12), as well as a large wire case for receiving towels, operating gowns, etc. The closable dressing box consists of two parts, one of which fits over the other. In the side of each near the bottom is a row of orifices. When one part is shoved upon the other the openings which each contains are closed ; but when they are drawn apart the orifices are uncovered. In this condition the box is placed in the steam chamber filled with dressings. After the sterilization is complete and a short time is allowed for evaporation of moisture, the box is closed tightly by shoving one part over the other.

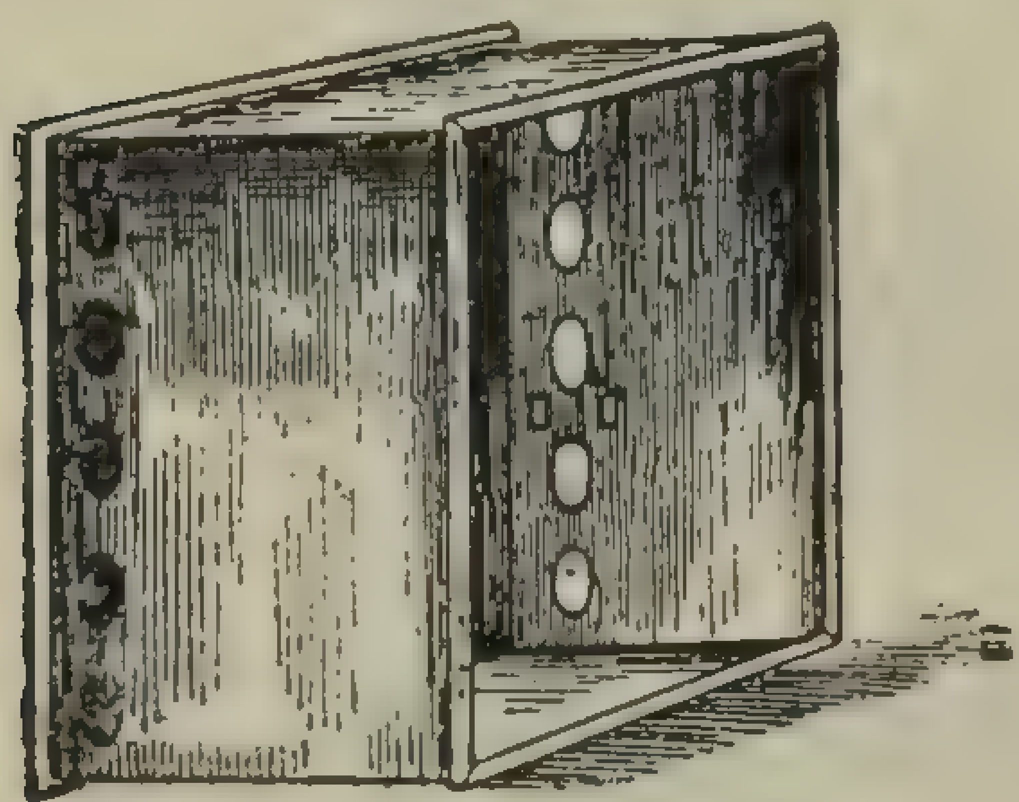

FIG. 14.

COVER TO BOX.

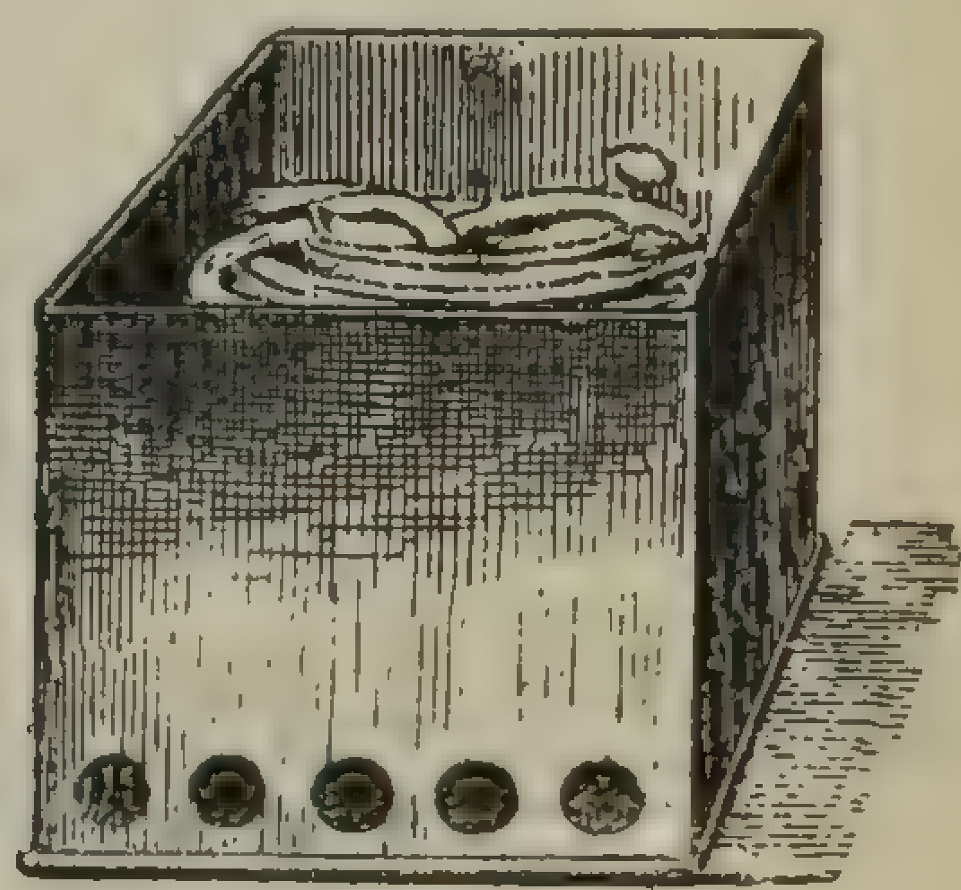

FIG. 15.

DRESSING BOX, WITHOUT COVER.

The surgeon may readily keep on hand a number of these boxes of different sizes filled with sterilized dressings (Figs. 13, 14, and 15). The articles may be asepticized by the use of alcohol or by setting the sterilizer upon a stove, this being the manner in which the soda instrument reservoir itself is used. The steam from the boiling soda solution enters the dressings contained in the upper chamber, and finds its exit under the cover. An adequate heat supply is essential, as the soda lye must boil actively. The sterilization occupies about three quarters of an hour.

Repeated experiments and observations have shown that the steam has a temperature of 100 degrees throughout the sterilizing chamber. This is afforded additional certainty by the still higher boiling-point of the soda, which is about 104 degrees C. Sterilizing tests with anthrax spores and dressings saturated with pus show complete destruction of the organisms after fifteen minutes.

But it must be understood that this apparatus is only adapted to limited requirements. Where large quantities of dressings are to be asepticized a sterilizer of greater proportions is necessary. With increase in the dimensions of the apparatus difficulty arises in securing for the disinfection a saturation of the steam in all parts of the chamber, and in having the circulating steam expel completely the air from the sterilizing compartment and its contained dressings.

It has been suggested to close the chamber air-tight and create a vacuum in it before allowing the steam to enter, thus avoiding the necessity of the latter having to force the air out. This might have an advantage in sterilizing articles difficult of permeation, for instance bundles of clothing ; but for a dressing sterilizer, it is unnecessary. The articles with which we have to deal principally—gauze, cotton, bandages, and towels, are relatively easy of permeation by the steam, so that with an apparatus of ordinary simple construction good results are obtained.

There are four requirements which, according to our improved knowledge of the subject, should be fulfilled in a sterilizing apparatus of large dimensions :

1. A previous warming of the articles.

2. Entrance of the steam into the sterilizing chamber from above instead of below.

3. The presence of a moderate amount of pressure.

4. A device for drying the dressings after they have been sterilized.

Formerly it was much feared that in a steam sterilizer there might be corners and crevices which the steam never entered. Frosch and Clarenbach have, by a series of experiments demonstrated that such "dead corners" do not exist. The steam disseminates thoroughly to all parts of the chamber if only they can be reached by it in a horizontal course. It does

not matter whether the sterilizer is cylindrical or round, and in any sub-compartments as provided, by placing in separate boxes, the temperature rises as rapidly as in the remaining portions of the chamber.

What may be a source of error, according to investigations made by Gruber, Frosch, Clarenbach, Teuscher, *et. al.*, is the entrance of the steam from below into the sterilizing chamber when the apparatus is of large dimensions. The direct attachment of a reservoir to the steam chamber and having it encompass the latter, is objectionable, as the dressings are directly saturated by the water as it becomes agitated in boiling. Also for filling the apparatus with steam, its entrance from below is unfavorable as the above investigations have clearly proved. Air being heavier than steam, tends to force the latter downwards, consequently it is expelled less readily when the steam enters the chamber from below and passes out above, than when it enters from above and expands over the air, permitting the latter to escape at the bottom. The filling of the chamber with steam, which alone marks the beginning of the sterilizing process, is accomplished more readily and with greater certainty, by entrance of the steam at the highest point. Teuscher demonstrated the relative differences in an apparatus made by Schmidt Bros. in Weimar, in which the steam could enter from above as well as from below and was under control of an alarm thermometer. For a trial disinfection, two folded woollen blankets were used ; the dimensions of which were respectively 25 by 60 cm. In the admission of steam from above a temperature of 100 degrees* was reached in about 17 minutes. In its entrance from below the same temperature was not attained for 22 minutes and 20 seconds, or fully five minutes later. Teuscher showed, as Pfohl had pre-

* In referring to temperatures the Centigrade scale is understood throughout this work when not specified.

viously done, that the steam entering from above gradually forced the air in front of it, expelling it from the apparatus below, and that the descending warm zone of expanding steam could plainly be felt on the outside of the cylinder. Not until the latter was hot throughout did the steam begin to escape at the bottom. If steam be allowed to enter the chamber from below, it begins at once to emerge through the orifice at the top—an indication of its unequal admixture with the air.

A moderate amount of pressure in the apparatus guarantees a more rapid and thorough permeation of the article sterilizing, besides a uniformity of temperature and the avoidance of condensation. A pressure of $\frac{1}{5}$ of an atmosphere, as provided by B. Retschel and Henneberg in their large disinfectors for hospitals and cities, insures a temperature of 102° C.

The previous warming and subsequent drying of articles sterilized, are important for preventing and overcoming the saturation from condensation. If the warming be thorough, a device for drying is unnecessary. It is not so much the live steam that wets the dressings, as it is the condensation which takes place when the steam is cooled. The latter occurs more particularly when hot steam comes in contact with cold articles. Hence the dressings that are in a cold chamber into which steam enters are especially apt to be saturated. The advance warming may be accomplished by having the sterilizing chamber constructed with double walls, between which the steam is conducted before it enters the chamber. A mechanism for drying consists in passing hot air over the articles after the disinfection is completed.

The adjoining apparatus of Lautenschläger has been used in the von Bergmann Clinic for nearly two years for the sterilization of surgical dressings and has always proved satisfactory. It consists, as shown by Figs. 16 and 17, of two copper cylinders (M and N), one of which fits into the other; the outer cylinder is enveloped in a mantle of asbestos (A), coated with loco-

motive varnish or with linoleum, as has recently been used. The space (O), several centimetres in width, between the outer and inner cylinders, is about half filled with water, the height being indicated by a gauge (W) at the side. The water is boiled by means of a gas jet (F). Steam ascends in the space

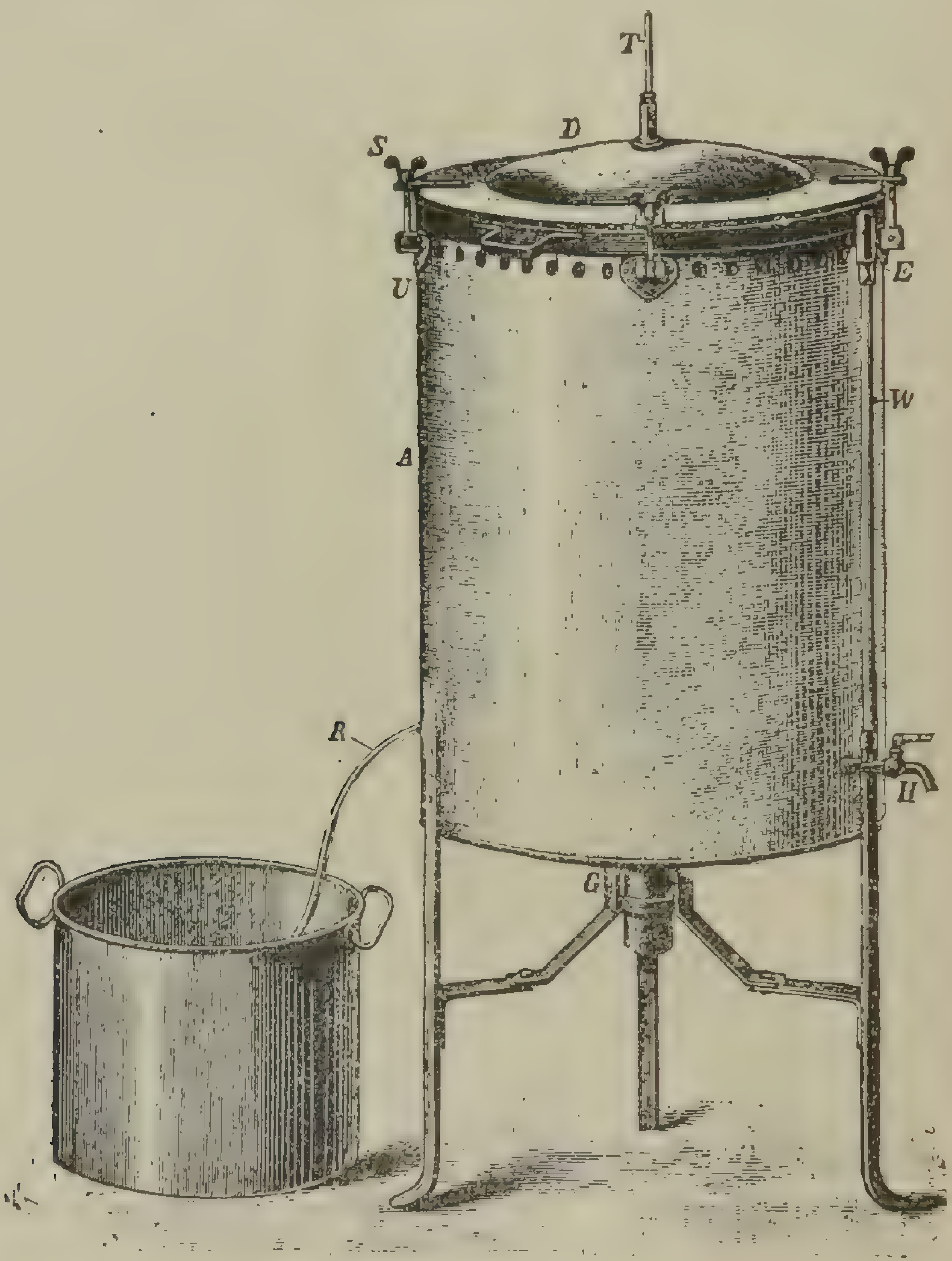

FIG. 16.

STEAM STERILIZER FOR DRESSINGS (LAUTENSCHLÄGER).
Side View.

O, and enters through perforations (V) around the periphery, at the top of the apparatus, the chamber enclosed by the inner copper cylinder, which is designed to receive the dressings. When the sterilizer is closed by the cover (U), the steam cannot escape above, but passes downward in the direction of the arrows and has its exit from the chamber through the tube R.

It is conducted through a coil of lead pipe to be condensed in a cooling vessel filled with water. The cover (D) closes hermetically, and is fastened

by means of a screw (S). In the middle is placed a thermometer (T). The apparatus is filled with water, through the gauge W, aided by a funnel placed at E. When the water in the space O is heated by means of gas, the temperature of the inner chamber and its added contents has been raised before steam forms, and the latter encounters the dressings already warmed. A close-fitting cover, together with the narrow diameter of the outlet for the

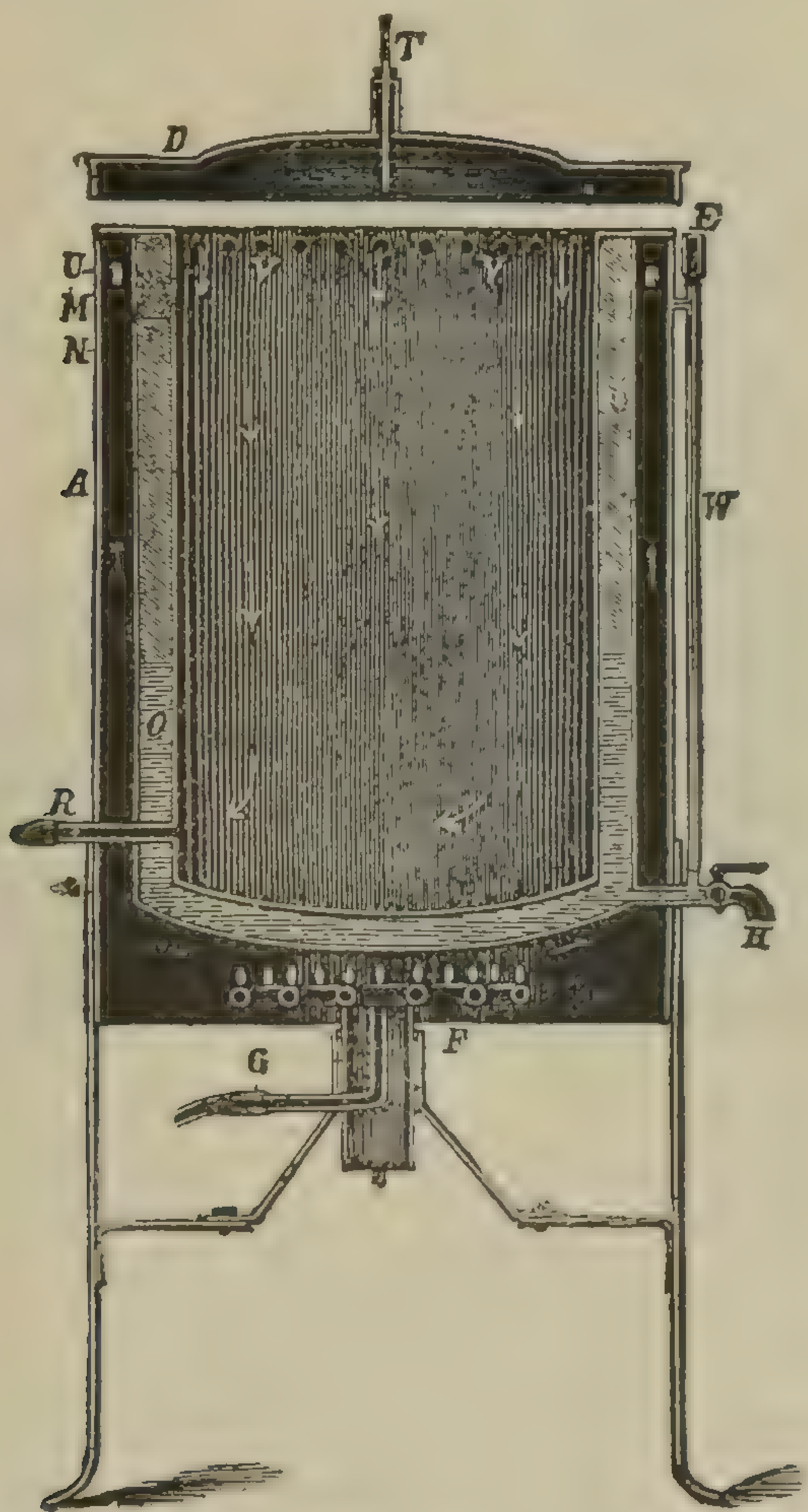

FIG. 17.
DRESSING STERILIZER.
Vertical Section.

steam, guarantees a temperature of 100° C., and also a moderate pressure, which we have found by repeated observation amounts, approximately, to 26 mm., or about $\frac{1}{30}$ of an atmosphere. With the apparatus closed and arranged for use, the sterilization is continued forty-five minutes after the temperature reaches 100° C. in the steam chamber. The dressings are then removed aseptic.

The steam which escapes from the sterilizer may be collected in a condenser situated close by; or, where there is a hydrant water supply, it is still better to condense the steam in a cold coil and conduct the distilled water back to the boiler, or use it as sterilized water for operations. (*Vide* Chapter XIII.)

Alcohol, as well as gas, may be employed for heating, or, in hospitals where steam is in use, this may be conducted directly to a large boiler through a pipe.

Round tin boxes (Fig. 18) set into the sterilizer, answer for dressing receptacles. They have a tight bottom and a close cover. In the sides near the top and bottom are lines of perforations which permit of being closed by metal

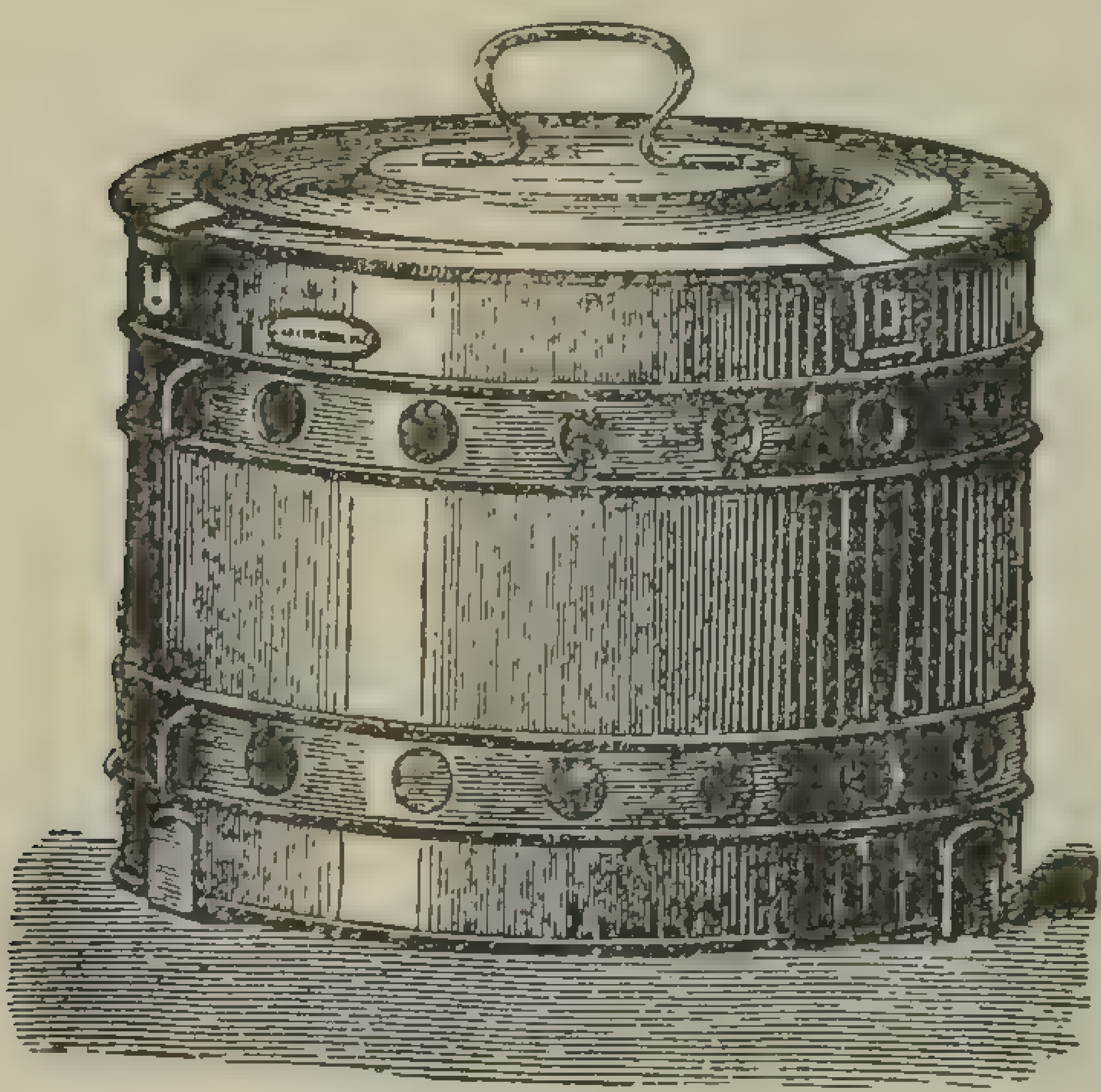

FIG. 18.

CLOSABLE BOX IN WHICH DRESSINGS ARE STERILIZED IN STEAM.

FIG. 19.

DRESSING BOX ENCLOSED IN A LEATHER CASE.

bands. The dressings, ready for use, are placed in the receptacles, and, with the perforations open, these are set into the sterilizer. Steam is developed so forcibly that the entire chamber is filled in a quarter of an hour, unless the contents are firmly packed. The dressings are only slightly saturated, having been thoroughly warmed previously. If the receptacles are allowed to stand for a short time after removal, uncovered and with perforations open, the dressings become perfectly dry. The bands are then closed over the orifices, and the cover is replaced. In private surgical practice these boxes may be carried about in a leather case (Fig. 19).

The time required for an exact sterilization of the dressings, if the latter are not compressed so as to offer special resistance, is thirty minutes, after the apparatus is filled with steam. The filling of the boiler with steam

depends upon its capacity and the efficiency of the heat supply. In Lautenschläger's sterilizer the time as stated, is fifteen minutes from the moment the steam begins to develop, until the chamber is completely filled. As soon after application of heat as is indicated by active boiling of the water and the development of steam, the dressings are set into the chamber, and after three quarters of an hour they may be removed as reliably sterile.

The various sterilizing devices of Schimmelbusch detailed in the foregoing chapters are admirable in their purpose and execution. It appears, however, that an additional feature might be incorporated in a combination sterilizer: that of asepticizing simultaneously water. The translator accordingly introduces the following design which is intended to meet the requirements of the general practitioner as well as the specialist in surgery, obstetrics, and gynæcology.

As shown in Fig. 21 it consists of a boiler (*B*) in which the water is sterilized, a tray (*C*) containing soda solution in which the instruments are sterilized, and an upper chamber (*E*) for sterilizing the dressings.

The steam for the latter is generated in a jacket of water (*A*), which envelops the lower boiler and upper instrument tray. The dressing chamber is provided with double walls separated by a narrow space which corresponds to the outer water compartment below, the communication between the two being direct. Through the upper intervening space steam ascends from the water jacket to enter, through a line of perforations, the inner chamber *at the top.* Hot air passes up around the dressings through the outermost space (*K*), so they are warmed before the steam encounters them. The water jacket extends from the bottom of the water boiler on all sides upward to the top of the instrument tray. It has drain (*I*) and inlet pipe (*G*) attached. The inner walls of the water jacket form the walls of the boiler for sterilized water on four sides and below. Resting into the boiler above is the shallow instrument tray with soda solution. Above the tray is the chamber for dressings.

In the latter are contained two sub-compartments (*F F*)—small closed boxes—with two rows of perforations in the top and bottom, left open for entrance of steam while the dressings are sterilizing, afterward closable to preserve them uncontaminated. The steam, after permeating and traversing

the dressings—gauze, cotton, bandages, etc.—contained in the boxes in the upper chamber, escapes through a vapor pipe at the side into the open air, or may, in case of an apparatus of large proportions, be conducted through a coil of pipe and condensed in a vessel of cold water.

Supply and drain pipes are provided to the water boiler so that it may be filled, or sterilized water drawn off, as desired.

The whole apparatus is closed at the top by a tightly fitting cover which sits into a water seal around the periphery.

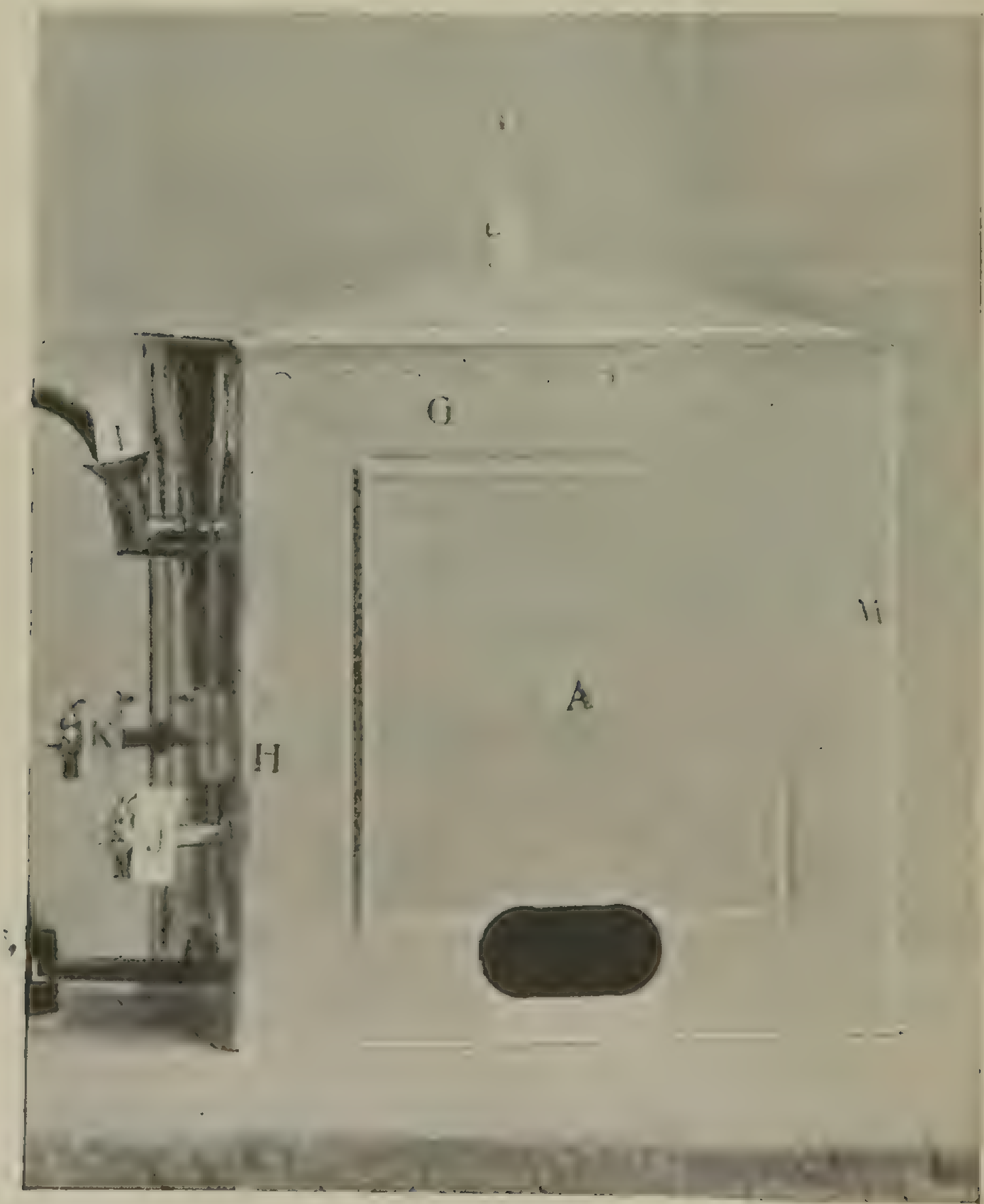

FIG. 20.

COMBINATION STERILIZER FOR WATER, INSTRUMENTS, AND DRESSINGS (THORNBURY).

A thermometer for registering the temperature in the steam chamber projects through the cover in the centre as shown in Fig. 20. The temperature here and in the boiling water will be found to be uniformly 100° C and about 104° C in the soda solution. The apparatus is heated by means of a gas pipe (*J*) running underneath and containing a number of jets so that the heat may be distributed over as great an extent of surface as possible. The alcohol lamp may also be used for heating. Owing to the compactness of the apparatus, its comparatively small size, and the provision for rapid heating in use of gas, the entire sterilizing process occupies but a short time.

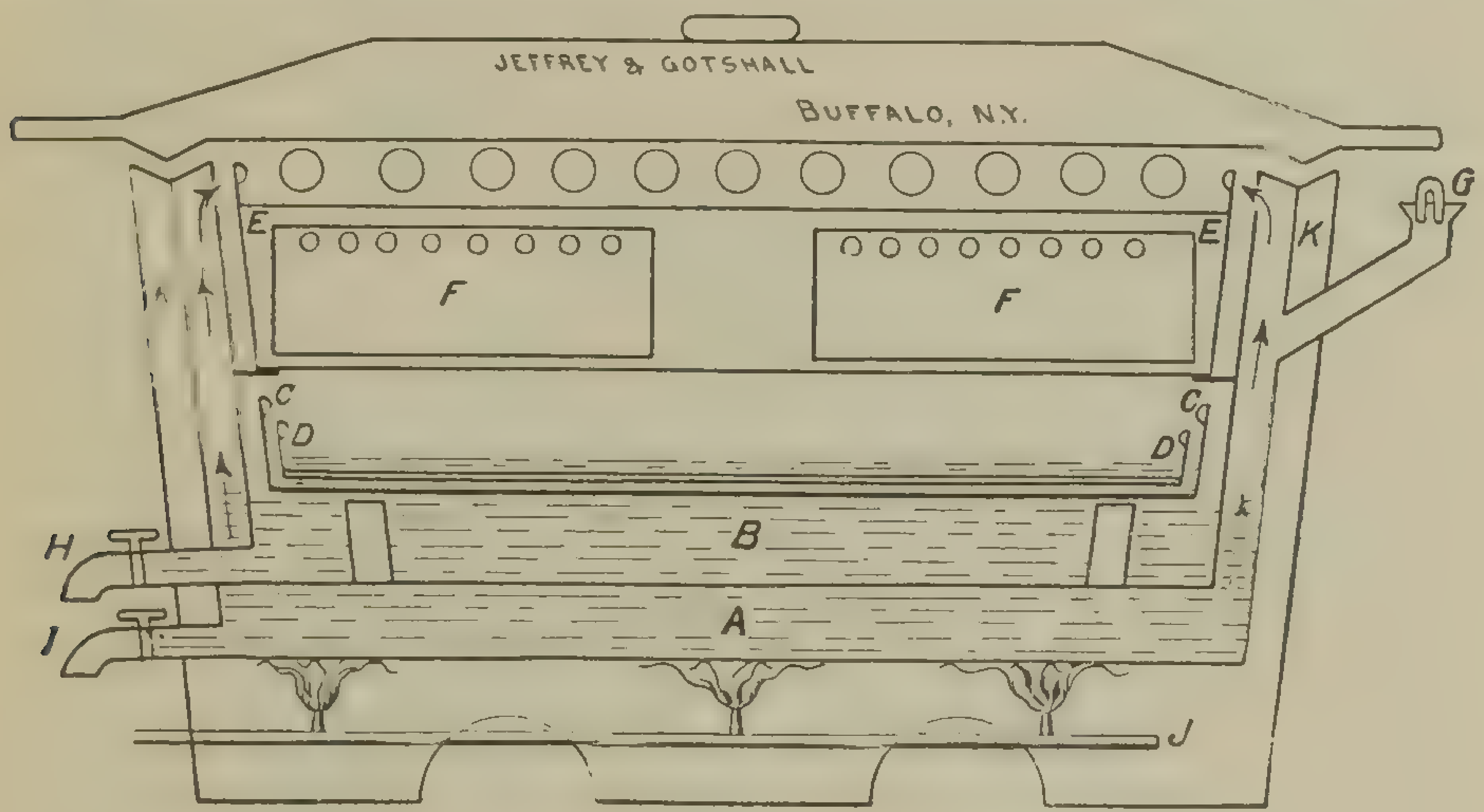

FIG. 21.
COMBINATION STERILIZER (THORNBURY).
Vertical Section.

A, water jacket; *B*, water boiler; *C*, soda tray; *D*, instrument tray; *E*, upper steam chamber; *F*, boxes for dressings; *G*, supply pipe to jacket; *H*, tap to sterilized water boiler; *I*, faucet to water jacket; *J*, gas supply pipe; *K*, hot-air chamber.

The water and soda are boiled in three to five minutes—the instruments sterilizing in the soda,—the upper chamber is filled with steam in twelve minutes, and in twenty-eight minutes the dressings are sterilized.

Two boxes of dressings may be asepticized at one time, and in the intervals a quantity sufficiently large to last for a number of operations, so that, in case of emergency and want of time, only a delay of about ten minutes is occasioned. This short time for sterilizing the instruments and water may occupy the interval of details preliminary to the operation.

The dressings, after having been asepticized, are removed in the small boxes (no secondary handling and contamination being permitted) and allowed to dry out, although there has not been much saturation through condensation,

owing to the dressings having been warm before the steam encounters them. They sit directly over and rest upon a tray of hot soda solution ; besides the steam is generated rapidly, is *saturated* and under considerable tension, and consequently has not much tendency to condense on the articles.

FIG. 22.

THORNBURY STERILIZER.

A, main body of apparatus; B, water seal; C, soda reservoir removed; D, instrument tray with contents, removed; E, sub-compartment for gauze, cotton, bandages, etc., slightly elevated; F, dressing box No. 2 removed, cover raised; G, steam chamber which contains dressing boxes; H, water jacket; I, supply pipe to water jacket; J, outlet to jacket; K, tap to sterilized water boiler; L, gas-pipe; M, hot-air interspace.

To cause evaporation of any moisture that may have occurred, and dry thoroughly the dressings so they may be preserved for future use, hot air may

be passed through them in a manner to be hereafter described. The dressings having been sterilized and dried, keep aseptic indefinitely in the tightly closed boxes. The latter are readily transportable, so the surgeon may have sterilized gauze constantly at hand in his private practice. In using this combination sterilizer, first the boiler is filled with water ; second, a one-per-cent. soda solution is placed in the tray, and in the latter the instruments are submerged in a shallow wire basket (*D*). Next the boxes are filled with dressings (leaving the cover and bottom orifices open) and set into the sterilizing chamber. Water is now allowed to flow from the hydrant to fill the jacket, and then the gas is turned on, or the alcohol lamp adjusted. After the sterilizing process is completed the water is drawn from the jacket through a faucet at the side, and water from the hydrant is allowed to course through around the sterilized water in the boiler, cooling it for immediate use. The instruments have been sterilized in the soda which has boiled, and are now taken out and set into a tray containing a cold solution of carbolic acid and soda. The gas or alcohol flame allowed to continue generates dry heat (the jacket being empty), which takes the same course to dry the dressings as the steam did in sterilizing them. This constitutes the apparatus and its working complete.

It is made in two styles. No. 1 entirely of tin ; No. 2 of copper with Russian iron cover.

The dimensions are : length, 17 in. ; width, 13 in. ; height, 18 in.

The third requirement of a dressing is that it shall work antiseptically and prevent as far as possible the development of bacteria in the wound secretions. This is particularly important where we have to deal with wounds already infected, but is none the less applicable to those which are recent and have occurred under aseptic circumstances. The wound secretion is such an excellent culture medium for low organisms, that individual bacteria which gain entrance to saturated dressings would multiply to an enormous extent, if there were no special influence to antagonize them.

It was formerly supposed that an antiseptic property might with great certainty be imparted to the dressings by impregnating them with antiseptics. The materials prior to use were

dipped into a germicidal solution, and then either wet or pressed out were applied to the wound; or else they were used dry after the impregnation, and the secretions were required to re-dissolve the antiseptic thus suspended. The trials which have been made with the various antiseptic agents in this way are very numerous.

In later years we have become convinced that through a certain property in dressings, viz., dryness, there is imparted more anti-microbic influence than by all antiseptics with which we have thus far experimented. There is no means which, in so simple, non-injurious, and at the same time more efficacious manner, prevents decomposition of the wound secretions in dressings—the evaporation of the coagulated products of secretion. Moisture is the essential living constituent of low organisms; dryness is the germ's greatest enemy. Remove from a bacteria culture medium its contained moisture and growth of the organisms ceases. If we provide in our occlusive dressings for drying out of blood, pus, and wound secretions we prevent the development of germs. It is the meritorious work of the Esmarch school, especially of Neuber, to have placed in its present light the importance of dry dressings.

Schlange, in the von Bergmann Clinic demonstrated by experiments how promptly dryness works against every form of germ life. He saturated layers of gauze with aqueous extract of beef or nutrient bouillon and inoculated the upper surface with the green pus bacillus. The layers of gauze thus inoculated were placed on glass plates, and some of the latter were left open so that evaporation of the fluid could take place. It was here observed that growth of the micro-organisms was very limited. Other plates of the same series were covered to prevent evaporation, and the bacilli proliferated luxuriantly, giving rise in a short time to their characteristic green color and growing through the entire thickness of the gauze. Again,

when evaporation was allowed to take place after the organisms had permeated the gauze for a few centimetres, the area of extension of the bacilli became overrun in a short time by the rapid advancement of the dried zone in the nutrient media, and further vegetation ceased.

In order to facilitate the drying out of the dressings, the proper material must be selected and so applied that evaporation of the secretions is in no way interfered with. Gauze and moss are to be preferred, as they not only absorb large quantities of discharge, but have the property of permitting rapid evaporation of the watery constituents in the absorbed secretions. The interlaying, or external application of layers of impermeable material over the surface of the gauze, is contraindicated.

Dryness is vastly superior to the use of impregnation with antiseptic solutions, as it counteracts germ development without damaging the tissues of the body. The application of antiseptics in dressings is always a *remedium anceps ;* a weak solution does not prevent the germs from multiplying, while a strong solution proves doubly dangerous, as it has a destructive influence upon the tissues of the body as well as upon the germs. It is not necessary to have presented at once a general intoxication ; the local effect is often sufficiently manifest and troublesome. There frequently occur under the impregnated dressing symptoms of intense irritation, and increased secretions together with cutaneous eczema place in question the propriety of the whole antiseptic treatment. We have to consider, not only a certain amount of idiosyncrasy to the antiseptics contained in dressings, but also the susceptibility to the effect of the chemicals used in disinfecting the skin preparatory to operation. The value of antiseptics in dressings has been over-estimated. We must recognize that it is not in water or bouillon that we have the development of bacteria to prevent,

but rather in rich, nutrient, albuminous substrata, which it is true do not absolutely neutralize the applied agents, but do markedly reduce their efficiency. The layers of dressing immediately covering the wound are rapidly washed out by the secretions which are poured forth, and are thereby rendered valueless.

It is difficult to maintain a continued and uniform quantity of antiseptic substance in impregnated dressing materials. The chemicals undergo decomposition after long intervals, not only in the dressings covering the wound, but also in dry and cautiously preserved packages. Carbolic acid evaporates, and corrosive sublimate enters into ineffectual combinations. Consequently packages of cotton and sublimated gauze, after preservation for from one to two years, contain only insignificant traces of the original abundant supply of bichloride. A good impregnation can only be accomplished by the use of resinous, oleaginous substances or glycerine, because the antiseptic without these, does not remain in suspension, but precipitates upon drying. Such combinations vitiate the absorptive power of the dressing materials, however, thereby depriving them of a property the importance of which we have just made explicit.

In the von Bergmann Clinic all wounds in which the drying out of the dressing could possibly be achieved, have for years been treated with a sterilized and good absorbing article—gauze or moss, the use of impregnation being entirely dispensed with. Moist dressings covered with impermeable layers of oiled paper or guttapercha are avoided, as they facilitate materially the development of bacteria in the wound's secretions. Such dressings cannot be allowed to remain for more than twenty-four hours in suppurating wounds without giving rise to a perceptible, foul odor. In only two instances is the favorable working of the dry dressing of wounds inapplicable: first, where we have to deal with a tenacious, thick or, perhaps

ichorous discharge; second, in the tamponing of wound cavities.

The tenacious secretions are absorbed with difficulty by even gauze and stagnate under the dressing, so that, used in tamponing wound cavities, a drying out from the depths cannot take place. Here the requirements for an antiseptic material inserts itself for the immediate covering of the wound, while for the outer layers, as before, evaporation remains worthy of effort.

For imparting an antiseptic property in case of the wound tampon, neither sublimate, carbolic acid, nor salicylic acid are adapted, but no remedy better than iodoform. Uninfluenced by the numerous attacks made against its use in the past few years, this remedy maintains its place in the list of dressing agents, and is to the surgeon indispensable, even though from a bacteriological standpoint its efficiency has been placed much in question. No other agent prevents with such certainty the decomposition of wound secretions in tampons, and at the same time works so slightly irritant and toxic. But the iodoform dressing should not be made by saturating the gauze with an ethereal solution or glycerine emulsion. In presence of the former, the iodoform decomposes readily, liberating iodine, while the latter impairs the power of absorption. The better way is to simply powder the iodoform into the gauze. Unfortunately gauze thus made cannot be sterilized in steam as the iodoform is thus destroyed.

In the von Bergmann Clinic this dressing is prepared by sprinkling sterilized gauze with boiled water, then distributing iodoform over it, rubbing it in with a small sterilized pledget, and then ironing the gauze with a sterilized compress, after which the material is preserved in a sterilized receptacle. For ordinary occasions it is better to simply rub the iodoform into the gauze shortly before using it. In wounds with a foul,

tenacious discharge, instead of iodoform, oxalic acid, oxide or chloride of zinc, may be used to advantage. The better application is a combination of acetate of aluminum 3 %, with chloride of zinc in a 1 % aqueous solution; the gauze is dipped into this solution and is then pressed out thoroughly and laid in thin layers over the wound. Impermeable materials are also omitted in this dressing, and layers of gauze and moss used for external covering.

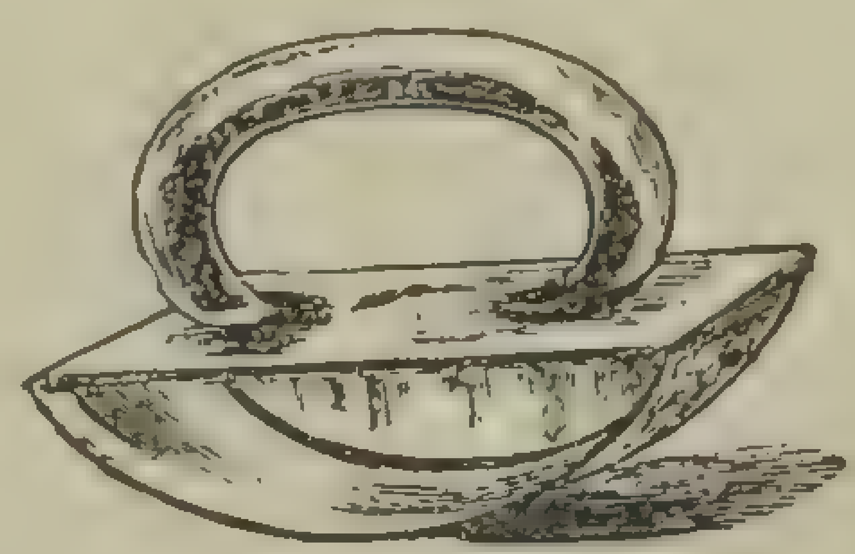

FIG. 23.

GLASS COMPRESS.

Although from an aseptic standpoint, and by reason of cheapness, the personal preparation of sterilized articles of dressing is superior to the use of impregnated and asepticized factory supplies, the latter cannot be entirely dispensed with. In case of emergency, for instance, where aseptic material must be in readiness, and where neither time nor circumstances permit of a sterilizing apparatus being used, dressings thus provided have their full range of propriety. But surgeons who strive to have their results infallible will conduct the sterilization of their own dressings, or assign the work to a skilled assistant.

The proper wrapping of packages of dressings prepared by manufacturers is a very important matter. Sheet-iron boxes or cases afford a very excellent safeguard against saturation of any part of the package, and a subsequent liability to the development of organisms. But usually the simple paper, pasteboard, or parchment covering will answer. The packages must be sterilized after they are filled with dressings cut

of the proper dimensions, so that asepsis of the wrappers as well as the contents is insured. The closure of the package must be effected without the contained articles being disturbed. These different requirements are easily met in various ways.

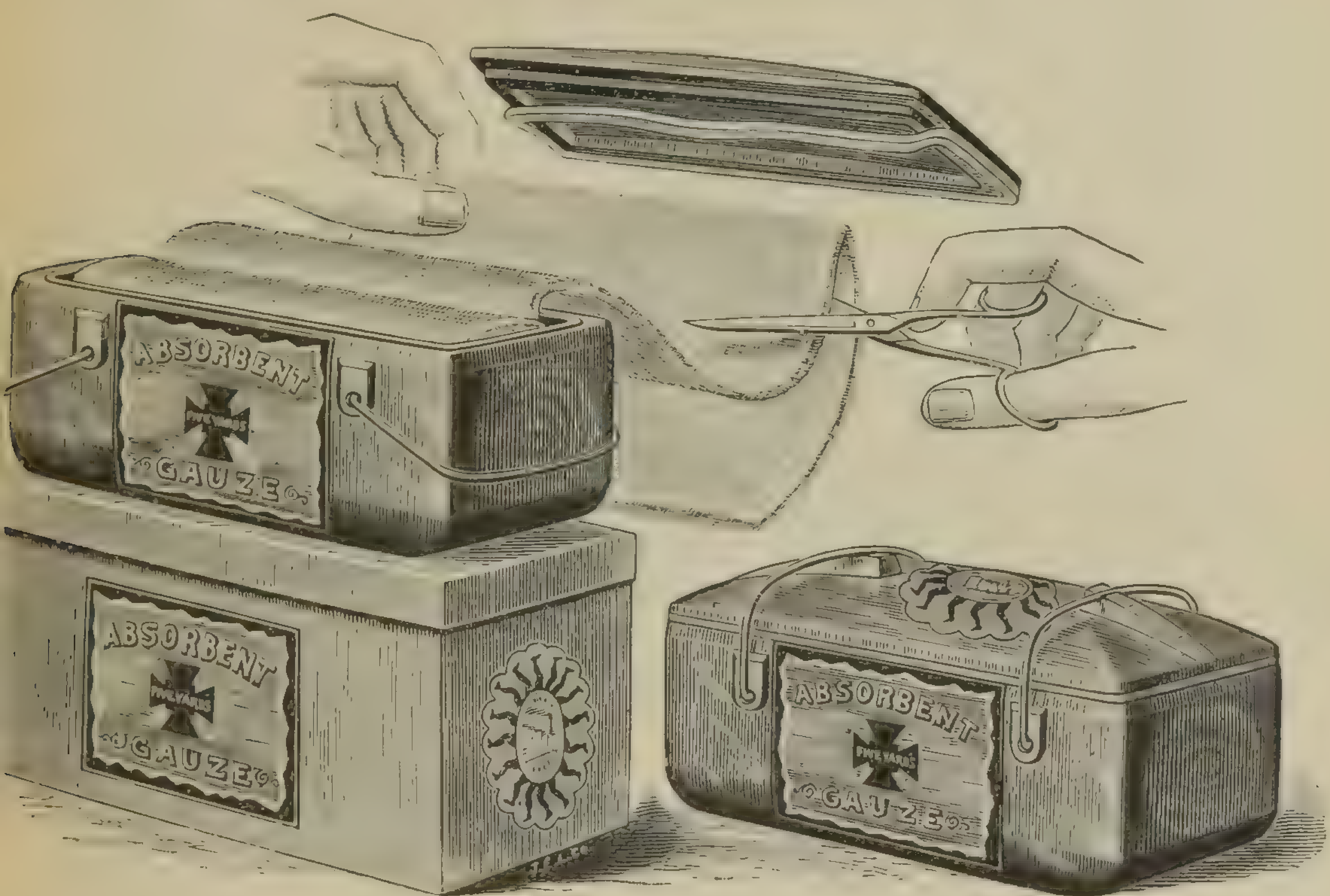

FIG. 24.

LEE'S GLASS BOX JARS CONTAINING ASEPTIC GAUZE.

TRANSLATOR'S NOTE.

In this country one of the most reliable sources of aseptic surgical supplies is the J. Ellwood Lee Co., of Conshohocken, Pa. I have taken occasion to investigate the methods employed by this firm, and have noticed the quality of their products. I therefore have no hesitation in expressing an opinion with reference to the latter. The daily capacity of the firm is 13,000 yards of gauze, put up in various forms. The work is conducted as follows: First the gauze is bleached, it is then washed thoroughly in boiling water, after which it is submerged for some time in very hot water. Next it is run through a drying machine, and wound upon sterilized rollers. The entire process takes place automatically, and the materials are not encoun-

tered by the hands of any employee. After the packages are wrapped, they are re-sterilized in steam. One form of package, which is very popular, is a small air-tight box or "carton," containing five yards of aseptic gauze. After being sealed, these packages are placed in boiling paraffin, and a waxy coating applied, which is increased in thickness by repeated submersions. One such package serves for a single large surgical dressing, and no gauze is left over to become contaminated after the parcel is broken. Another form of package prepared by J. Ellwood Lee is the glass box jar shown in Fig. 24. This contains five yards of aseptic gauze, and is air-tight. After the box has once been opened and part of the material used, the remainder may be re-sterilized by placing the box in boiling water or steam. The gauze may be withdrawn without removing the roll as indicated in the illustration.

This jar is of convenient size, and may answer several useful purposes after its contents have been exhausted.

The firm referred to also manufacture five-yard hermetically sealed "cartons" of iodoform gauze (10 %), which is reliable.

I simply mention these latter products for the benefit of those who through emergency or other circumstance may not be in position to sterilize their dressings. This will often be the case with practising physicians who do a limited amount of surgical work.

CHAPTER VIII.

ASEPTIC SUTURES AND LIGATURES.

Non-Absorbable Material: Silk and Wire Sutures—Absorbable Material: Catgut—Disinfection of Silk by Boiling—Von Bergmann's Method of Sterilizing Silk in Steam—Advantages of the Same—Linen as a Suture Material—Sterilization of Wire Sutures—Sterilization of Catgut—Lister's Original Method—Kocher's Juniper-Catgut—Von Bergmann's Sublimate Catgut—Hot-Air Sterilization of Catgut—Disinfection in Xylol according to Brunner—Advantage of the Corrosive-Sublimate Treatment of von Bergmann—The Process of Absorption in the Body and its Duration.

A variety of materials was recommended and used in the pre-antiseptic period for suturing and ligaturing.

Surgeons formerly endeavored to close vessels and wounds by means of sutures without obtaining a reaction. Unfamiliar with the true cause of suppuration and inflammation, but conjecturing that the secret of the results lay in the suturing material used, they always sought after a new article.

Now we know that neither the material, its color, coarseness or fineness have any influence whatever, but that the absence of reaction during repair is dependent on the asepsis of the material employed. Individuals come to acquiesce in the use of a reasonably reliable article, and to direct their efforts toward disinfecting the same with the greatest possible thoroughness.

To-day we use materials which are:

1. Designed to gradually undergo liquefaction in the tissues and subsequent absorption: absorbable materials; and

2. Articles which are to become permanently imbedded in the tissues, or which are removed after a certain time: non-absorbable materials.

By absorbable ligature, catgut is understood; while as non-absorbable, only silk and wire properly come under consideration.

The sterilization of silk is not a difficult task. But it is not sufficient, as many formerly supposed, to dip the threads for a few minutes into a disinfecting solution, unless we apply 5 per cent. carbolic acid or 1 per cent. corrosive sublimate; pathogenic spores, and also bacilli and cocci, which are imbedded in layers of fat, albumen, or dirt, may retain their virulence in such solutions for days, and even weeks. Also the impregnation of sutures with antiseptics dissolved in oil or fatty substances should no longer be practised, since Koch has established that antiseptics thus applied suffer almost a complete loss of their germicidal properties. The old English method of preparing silk ligature—the saturation of the material with a mixture of carbolic acid and liquefied wax (1 : 9)—has, with propriety, become universally obsolete.

For the sterilization of silk, heat is best adapted, and may be applied either in the form of boiling water or steam. The disinfection with hot air at 140° to 150° C. continued for three hours is too exacting, and its repeated application damages the sutures and causes them to become brittle. The disinfection by boiling is much employed, and many surgeons prepare their silk in this manner before each operation.

It may be combined very conveniently with the sterilization of the instruments, by winding the silk on glass or metal spools, and boiling it in the soda solution (Chapter VI.) Other surgeons boil their silk once for, perhaps, half an hour in water or some antiseptic, and then preserve it for use in a 5 per cent. carbolic acid, or 1 per cent. sublimate solution.

Very convenient small glass bottles have been constructed for this purpose. In these the sterilized silk, wound upon small rollers, rests in the antiseptic solution, and may be removed easily as required.

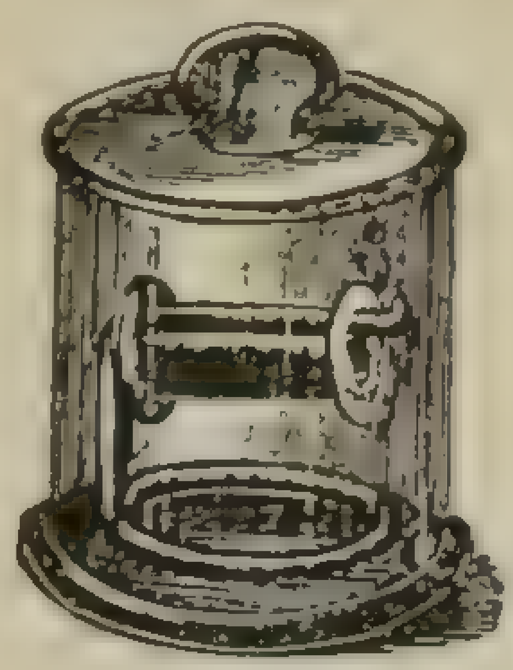

FIG. 25.

GLASS RECEPTACLE FOR PRESERVING SILK SUTURE IN SUBLIMATE SOLUTION.

For many years in the von Bergmann Clinic the silk suture has been sterilized in steam. The method employed consists in inclosing the silk, wound upon spools, in small metal boxes, and placing the latter in the steam sterilizer for three quarters of an hour.

In this manner, with the sterilization of the dressings, the suture material may also each time be sterilized. No injury is occasioned to the silk, even though the method be frequently repeated.

It is, moreover, unnecessary to renew the sterilization daily if we have constructed an efficient and tightly-closing box, as the one sterilization lasts for a sufficiently long time.

Advantages in the steam sterilization which are not to be underestimated are, first, the fact that the silk sutures are not impregnated with an antiseptic, and consequently cannot exert an irritating influence upon the tissues ; and, secondly, they remain dry, and dry sutures thread better and are more easily tied.

The preservation and transportation of the silk ligature sterilized in steam is also more simple and convenient. Appended illustration is of a small apparatus devised by the

author. It is a modification of the receptacle for silk ligature which has been in use for a long time in the von Bergmann Clinic (Figs. 26 and 27).

The apparatus consists of a small metal box (*a*) with folding cover (*c*) and hinged anterior wall (*b*). The rollers for the silk are composed of three firm rods, which revolve easily and permit readily of being removed. The rollers proper are not solid, but consist simply of two perforated end plates, which are united with one another by means of the rods. This facilitates the thorough circulation of the steam. The silk is wound upon these rollers, and the ends of the threads protrude through the linear openings in *a*.

With a quantity of silk wound upon the rollers the apparatus is placed for half an hour in the steam. Upon removal the cover (*b*) is closed. This clasps the threads by a firm bridge piece, and prevents them from slipping back as the box is used.

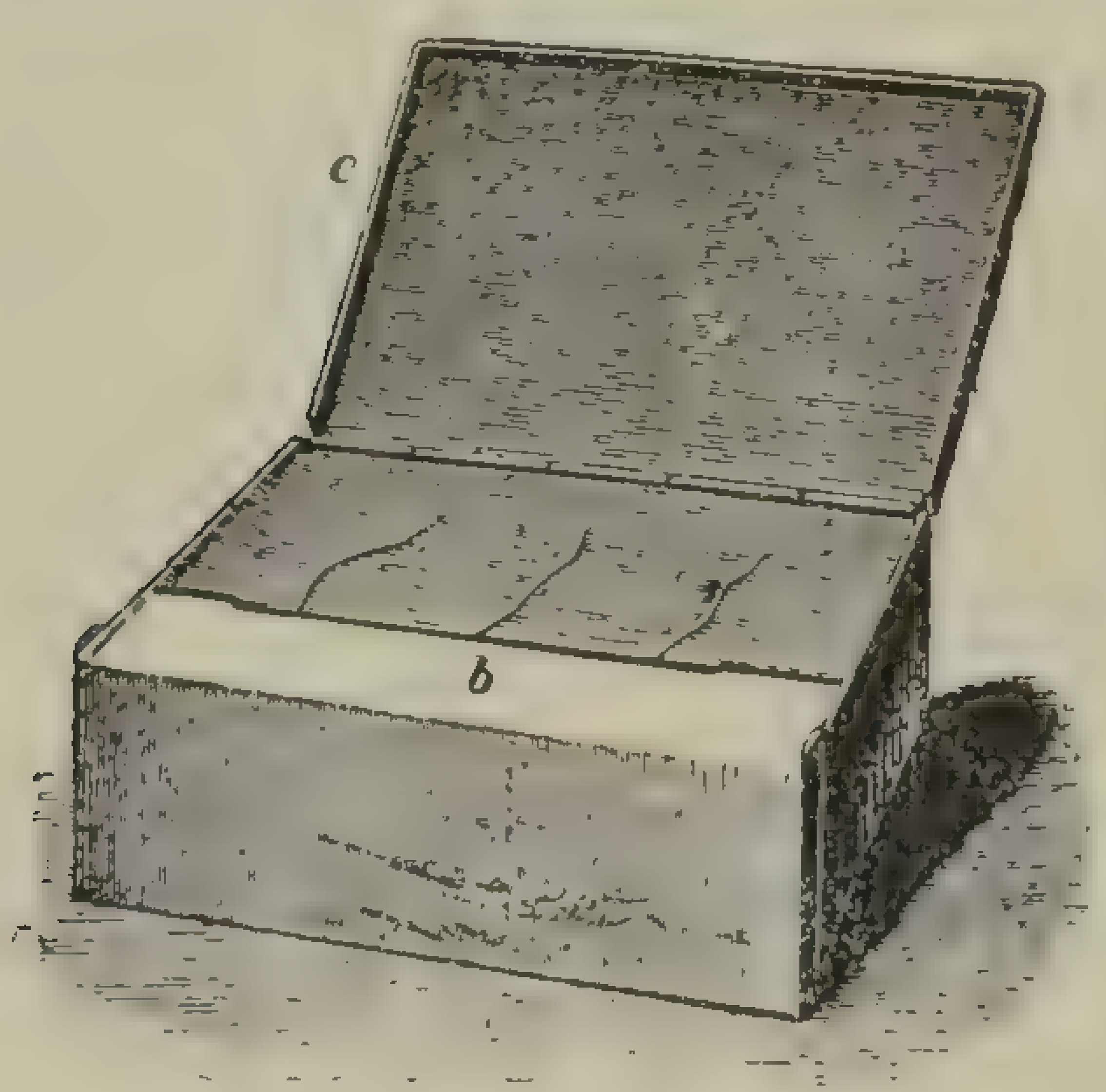

FIG. 26.

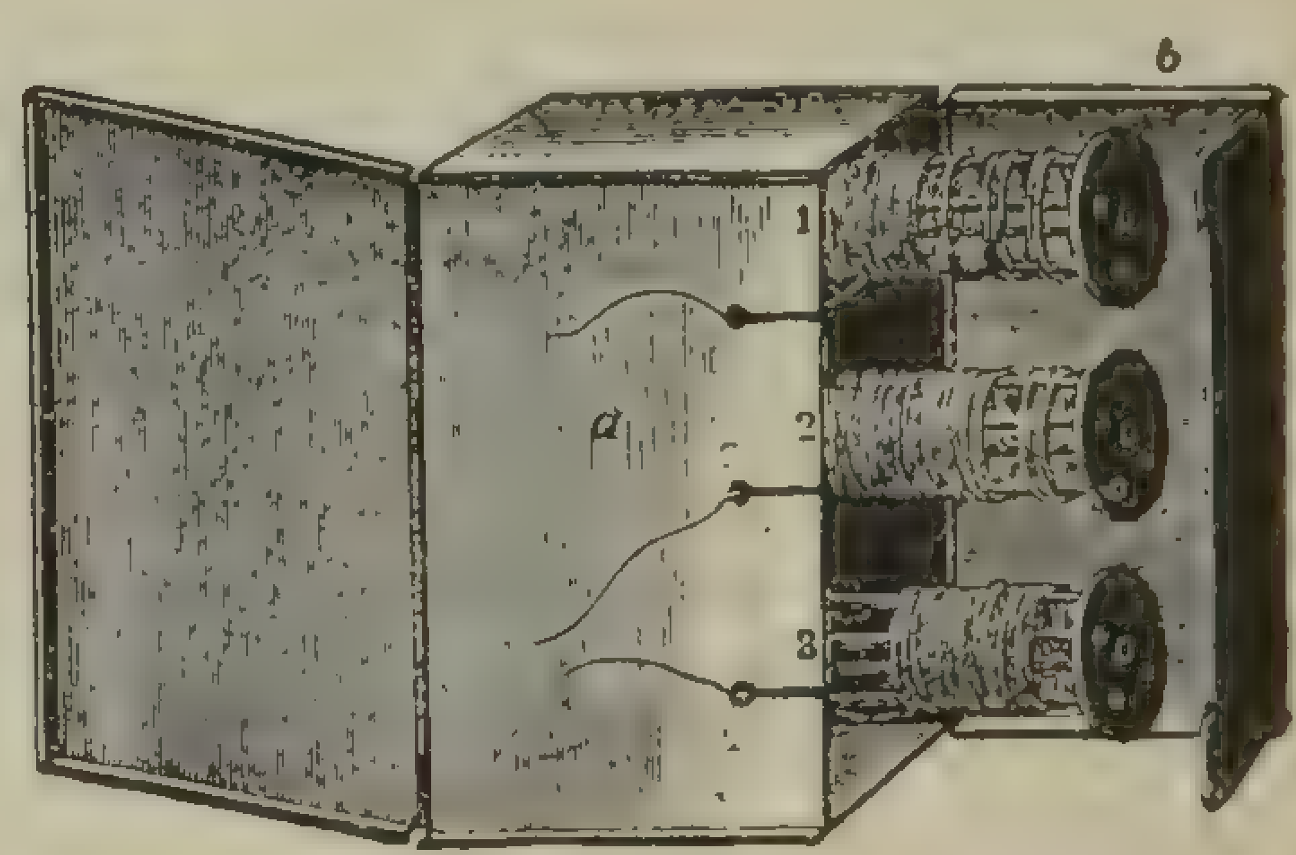

FIG. 27.

RECEIVERS FOR SILK LIGATURE STERILIZED IN STEAM (SCHIMMELBUSCH).

At the beginning of the present century silk was not universally the most desired material for sutures; linen thread was very much in vogue. Linen is still recommended for suturing, and endorsed by Heyder from Trendelenburg's Clinic. The latter article is almost sixty times cheaper than silk. That linen can also be sterilized as easily there can be no question; but as to whether it is as well adapted for suturing there is a

difference of opinion, and many surgeons after a trial of linen have returned to the use of silk. The silk is more conveniently handled, and permits of being tied more readily.

The metal sutures employed so extensively by individual operators, but the use of which in the von Bergmann Clinic is confined to the ligaturing of bone, may be asepticized by boiling shortly before using. If it is desired to preserve them permanently aseptic, the submersion in alcohol is preferable.

The endeavors to find an absorbable suturing and ligaturing material are very ancient. Dupuytren, A. Cooper, and V. Walther made attempts in this direction by using threads of organic material, of leather, and intestine. These efforts had also their special object and basis, as, owing to the want of asepsis, the inclosure of silk ligature could not be contemplated, and the casting off of the same in the process of healing of the wound had to be awaited. At that time, however, it was the universal custom not to cut ligatures close, but to leave long ends hanging out of the wound in order to be able to remove them with greater readiness after thrombosis had taken place in the vessel ligated.

But also to-day the advantage of an absorbable ligaturing material still holds good.

It has more than once been observed that in primary closure of wounds by silk or wire, the ligature at the beginning well imbedded in the tissues after a long period of time, becomes repelled and suppurates out. The primary union is satisfactory, but after weeks or months, in the line of suture an abscess forms, whereupon a fistula develops, and from the later the disturbing ligature escapes. Lister introduced six deep hemp sutures into the wound of an extirpated goitre or bronchocele, and after union observed the extrusion of all six threads in succession, in the course of eight or nine months. The imbedded silk or wire simply remains a foreign body in the

tissues, of which the organism endeavors to free itself as soon as a favorable opportunity presents.

Although Sir Astley Cooper even employed catgut ligature, the credit of first having introduced into surgery the use of the prepared intestine is undoubtedly due to Lister; for only upon the principles of asepsis was the question of an absorbable ligature to be solved. Lister first practically demonstrated the advantage of such a material, and gave the directions for the antiseptic preparation of catgut.

The method consisted in the submersion of the commercial article for one month, in a mixture of carbolic acid (1 part) and olive oil (10 parts), with the addition of a sufficient quantity of water to secure the admixture of the oil with the carbolic acid. This original Lister catgut was used for a long time, and finally abandoned by Lister himself.

As may readily be understood from the method of preparation, there was little guaranty afforded of an aseptic condition, and from many sources we have complaints of severe infection resulting from the use of this material (Volkmann, Zweifel, and others). Lister himself later gave an improved method of preparing catgut, the new feature of which was chromic acid. The addition of chromic acid was to cause a greater degree of firmness, and give to the tied knots more stability. According to this new method the catgut was placed in a 5 per cent. aqueous carbolic acid solution, which contained chromic acid in the proportion of 1:4000. In this solution it remained for 48 hours, and then was preserved in carbolized oil (1:5).

More recently a great variety of methods for the preparation of catgut have been devised. As a natural consequence better results have been attained. Lister's efforts and the endeavors of his immediate followers were, as related, directed essentially toward imparting to the material, which softens readily in

blood and serum, a greater degree of hardness. Hence the prolonging of the treatment over months and the application of chromic acid. To-day we know that this danger is not so great, and that with a moderate amount of firmness, which may readily be obtained in a variety of ways, fear of a too rapid dissolution of the suture or separation of the knot is unnecessary. On the other hand, the importance of a thorough disinfection of the catgut has always assumed increased prominence. The difficulty of a thorough disinfection, together with the origin of this article from the bacteria-laden intestine, has continually occasioned opposition to the use of catgut, and indeed has induced many to completely abandon it.[1]

We know that the catgut is not, as the name really implies, obtained from the intestine of cats, but rather from that of sheep. According to Lister's description, the small intestine of the sheep is first detached from its messenteric attachment, then washed in water, and with an instrument similar to the back of a knife scraped over a board. The so-called "refuse," which is nothing else than the mucous membrane of the intestine, is thus rubbed off. The circular muscular tunic is also removed, so that there only remains the very thin submucosa (Halsted), which is converted, through inflation with air, into a delicate though well preserved tube-like structure. By twisting the latter the sutures are made, the whole tube being wreathed into a hemp-like cord, or only strips twisted together, according to the thickness desired.

[1] Such has been the case with Kocher in Bern and with J. Klemm, 1891, in the Dorpater Clinic. In both clinics there have been occasional mishaps in the asepsis attributable to the use of catgut. It must, however, be borne in mind that in these instances it has not been positively proved that the catgut was to blame; in fact, the catgut in the Dorpater Clinic was found to be free from bacteria. With the numerable factors which come opportunely into question in an operation, it would be difficult, without absolute evidence, to attribute to any particular moment the cause of failure in a procedure or, indeed, to assign to the same an intercurrent infectious influence.

Although catgut as prepared by the manufacturers is treated with alkaline baths, sublimate solution, and bleaching agents, and is thus to a certain extent disinfected, the raw material obtained from the dealers still usually contains many bacteria. At any rate, an additional thorough disinfection must be practiced, as it may contain not only innocent intestinal bacteria, but also pathogenic organisms. It is, indeed, not difficult to understand, with the prevalence of anthrax among sheep, that material containing such spores may sometimes be applied. Volkmann has reported two cases in which malignant pustules developed in the track of fresh wounds which had been sutured with catgut, and he is inclined to attribute these infections to such contamination of the catgut.

We have shown that submersion in carbolized oil is insufficient, as is also the treatment with chromic and carbolic acid, which play the most important rôle in the improved Lister method, as also in McEwen's method of preparation.

Kocher's procedure merits greater consideration. The latter consists in submerging the catgut for twenty-four hours in juniper oil, then placing it in 95 per cent. alcohol.

Von Bergmann treats the material with a 1 per cent. solution of corrosive sublimate in 80 per cent. alcohol. The preparation occupies at least forty-eight hours, but is better if continued still longer.

Raw catgut is placed in the sublimate alcohol, and this is renewed every few days until the fluid, which at the beginning was cloudy, remains perfectly clear. The catgut is then put into ordinary alcohol.

The knowledge of the superior disinfecting power of heat has recently induced surgeons to attempt its application in the sterilization of catgut. Steam and boiling water are inapplicable, as both rapidly cause softening of the catgut into a firmless coil and its subsequent transformation into a gelatinous

mass. According to investigations made by the author, this effect is unavoidable, excepting by the addition to the water of strongly caustic substances, as corrosive sublimate, chromic or carbolic acid. Hot air, on the other hand, is applicable to the sterilization of catgut. Reverdin and, independent of him, Benkisser were first to use this method, which consists in heating the catgut to 140° C. for three hours in a properly regulated hot-air sterilizer. Notwithstanding the great heat, the catgut retains its elasticity and firmness, although certain conditions must be observed, to avoid its becoming friable and useless.

Reverdin believed that the presence of fat in the catgut was the source of failure in the hot-air method of sterilization; this, however, is not the case. It is much more the water which is contained that causes damage in heating. In applying the hot-air method of sterilization, it is essential, in order to have remaining a material which can be used, to first dehydrate completely the catgut by submerging it in alcohol for twenty-four to forty-eight hours, or else heat the sterilizer very slowly in order that all the water will have evaporated before the high temperature of 140° has been reached.

The entire procedure is very difficult and complicated, and requires a degree of fatiguing exactness which precludes its general adoption.

After Benkisser had tried in vain to prepare catgut in hot oil and glycerine, Brunner found in xylol an agent in which the material could be sterilized by heat. In this the catgut may be submerged for hours at 100° C. or at the boiling point of xylol—130° to 140° C. From investigations made by the author, there is a variety of substances—for instance, the ethereal oils, oil of bergamot and oil of cloves, and also aniline oil—which permit of similar application. It is, however, a peculiar fact that at 100° C., and even their respective higher

boiling points, heated solutions as regards their power of destroying bacteria are of little value and occupy a place much inferior to boiling water. Thus Brunner found that vigorous anthrax spores placed in boiling xylol at 140° C. do not lose their virulence for one and one-half to two hours, and at 100° C. not for two and one-half hours. Anthrax spores of ordinary resistance, which were destroyed by boiling water in two minutes, and by steam in five minutes, were found by the author to be capable of growth after submersion in aniline oil for an hour at 100° C. If we employ, then, xylol in the sterilization of catgut, as Brunner has suggested, the process must be continued for a number of hours, as in the sterilization by hot air. Brunner submerges the catgut in xylol contained in closed vessels, and places the latter in a live steam sterilizer for three hours at 100° C. The catgut is then washed in alcohol and preserved in sublimate alcohol.[1]

After numerous practical and experimental investigations in the Royal Surgical Clinic, the original Von Bergmann method of preparing gut suture has been adhered to, for even the procedure recommended by Brunner is more complicated and difficult.

With this, as with the method of Benkisser-Reverdin, the catgut must be cautiously deoleated, otherwise, as in the latter instance, it becomes crisp and friable. In numerous steriliza-

[1] Dr. William G. Bissell of Buffalo, N. Y., has recently given a formula for the preparation of catgut which is as follows: The raw material is placed in a 1 to 1000 ethereal solution of bichloride of mercury and allowed to remain for six hours. It is then wound upon sterilized glass spools and re-introduced into the solution for six hours longer. Afterward it is washed in pure ether and boiled in absolute alcohol at atmospheric pressure for ten minutes, the object being to remove all traces of the bichloride.

The texture of the article remains unchanged, at least is not weakened, and it withstands bacteriological tests. Catgut prepared after this method may be obtained from the J. Ellwood Lee Company of Conshohocken, Penn.

tion experiments with catgut suture artificially impregnated with pus and anthrax spores, the sublimate-alcohol method proved itself throughout equal to the heat-sterilizing procedures which have been given. Frequent tests have shown that the catgut used in the clinic is always free from bacteria. That the catgut treated by the sublimate method must, however be free from fat, and that accordingly, if it is not produced by the dealers deoleated, the fat must be removed by ether, is a fact, to the importance of which Braatz first directed attention.

FIG. 28.
IMMACULATE CATGUT (BISSELL).

Most American surgeons are familiar with Fowler's aseptic catgut tubes, sealed after the ligature has been boiled in alcohol under pressure. The advantages claimed for this method are these :

1. The catgut is rendered absolutely aseptic after all handling in its preparation has ceased.

2. It is hermetically sealed against all forms of infection.

3. It is cut into suitable lengths for use, after inclosure in the tubes.

4. The surgeon may re-sterilize the articles if he desires by placing it in an oven heated to 100° C.

Investigations made by Drs. Bolton and Slee have proved that catgut removed from these tubes under aseptic technique, and placed in various culture media fails to reveal any germ life.

This was a corroboration of Dr. Hodenpyl's experiments.

The preparation of catgut according to the von Bergmann method is in detail as follows :

1. Sterilization of the glass receivers (Figs. 29 and 30), in steam for three quarters of an hour.

2. Winding of the ligatures on the glass rollers or glass plates.

3. Deoleation of the catgut by submersing it in ether and allowing it to remain for twenty-four hours.

4. The addition of sublimate alcohol after the ether is removed.

The sublimate alcohol is of the following composition :

Corrosive sublimate.........	10.0
Absolute alcohol...........	300.0
Aq. destillata...............	200.0

FIG. 29.

CYLINDER FOR CATGUT.

The sutures are wound upon a glass plate 40 cm. long.

5. Renewal of the sublimate alcohol every 24 hours. It must be changed at least twice before the disinfection is complete.

6. Removal of the sublimate alcohol and substituting ordinary alcohol. According as a stiff, or soft, elastic article is desired, the alcohol is used absolute, or glycerine to the extent of 20 per cent. may be added. Also the sublimate formula as in "4" may be retained. The receiver must always be kept tightly closed.

This method is easily executed even in private practice.

It is important for the practitioner to know the time which catgut requires for its absorption, and to understand the latter process. Accordant researches by Flemming, Tillmanns, Lesser, Hallwachs, and others have shown that catgut in the tissues of the body at first softens and then becomes infiltrated with leucocytes.

Very soon afterward it is interwoven by the living tissue and compressed, then transformed into a granular detritus which is either liquefied and absorbed or removed by the wandering cells (Tillmanns).

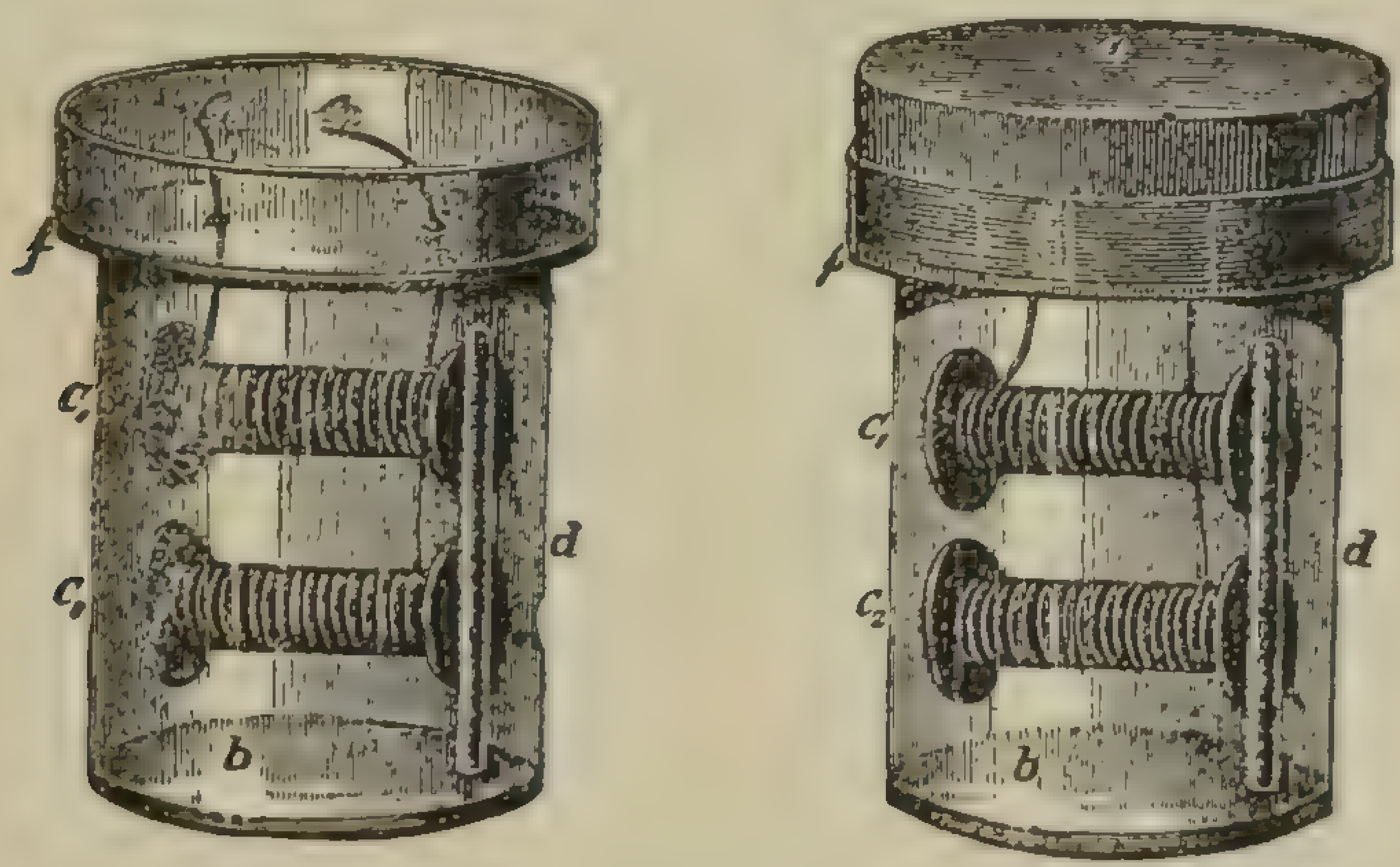

FIG 30.

RECEIVERS FOR CATGUT.

They are closed by rubber stoppers, a, which, like the receivers, d, may be sterilized in steam. The catgut is wound upon rollers, c, c_2; the ends of the sutures are passed through a glass plate, f, in the top of the vials.

These changes correspond exactly with those which inert particles of animal matter undergo generally in the living organism. The rapidity with which the absorption and obliteration take place appears to be uninfluenced by the method employed in preparing the catgut. As a rule, there is a tendency to underestimate the duration of this process. Lesser studied exhaustively the time which Lister catgut, obtained from England, required to undergo absorption in the bodies

of rabbits. Up to the 22nd day scarcely any change was detected ; and in three out of four cases he observed remains after 85 days. In investigations made by Hallwachs catgut ligature imbedded in the body of animals was no longer discernible after the end of six months. Operators have repeatedly complained that after intervals of four weeks and even longer, catgut, as silk suture has to be removed from the vagina after plastic operations, and occasionally catgut suture has been found in uterine and peritoneal cicatrices after one and a half and two years from time of its introduction, during an operation. The fear, therefore, that catgut used for suturing and ligaturing may be too rapidly absorbed, as has occasionally been expressed, is not well founded ; it persists much longer often than is desired.

CHAPTER IX.

ASEPTIC WOUND DRAINAGE.

Methods of Drainage—Absorbable Drains—Gum, Glass, and Caoutchouc Drainage Tubes—Capillary Attraction in its Application to Drainage.

ESCAPE of secretions from fresh and suppurating wounds may be accomplished in a variety of ways.

1. By making a simple opening for the discharge.
2. By introducing a tube.
3. By applying materials which work by capillary attraction.

It is not within the province of this volume to consider the subject of where and how the drainage opening is to be made with reference to the wound, nor to discuss how it is to be maintained, or the wound kept gaping. However, in a great number of operations, the creation of such opening, or the leaving of outer spaces between the sutures, suffices to conduct externally all that the wound should discharge.

In cases where anything more is necessary, there is no lack of suggestions. But whether glass tubes, gum, metal, or caoutchouc tubes be employed, or whether we choose horsehair (White), glass wool (Kümmel), silk threads, wicking, or some other article, we must always bear in mind that these materials can only be used in a strictly aseptic condition.

For the drainage of aseptic wounds, absorbable tubes (Neuber) were for a time very popular. The theory of their use was somewhat plausible, since first a tube is provided which secures removal of the secretions and which further,

simultaneous with union of the surfaces and discharge of the secretions, begins itself to disappear, finally becoming entirely absorbed, so that under the one dressing, even in deep and richly secreting wounds, complete union takes place. The material recommended by Neuber as absorbable, the tolerably expensive decalcified tubes made from the cortical portion of the large bones of cattle, and also the cheaper decalcified long bones of fowl (Trendelenburg, McEwen), as well as the bundles of catgut (Watson Cheyne), have, however, not fulfilled the expectations formed of them. Their application is not devoid of danger, and their function is too uncertain, as such a gelatinous bone tube often disappears in a short time—much sooner than desired, while again they remain for weeks unchanged. The majority of surgeons prefer to use non-absorbable tubes, and after the course of five or eight days, remove them with a change of dressing.

Of the various drainage tubes, those made of flexible rubber have, with propriety, had the more extensive usage, and only exceptional operators prefer tubes made of hard rubber or glass. In the employment of the latter, especially the glass tubes, a large assortment, embracing various sizes and lengths, is required in order to be able to supply each time a tube of just the proper dimensions. This is objectionable. The operator cannot divide this material into pieces of any length as he can ordinary rubber. The notion that the glass tubes and all those made from hard material drain better than the soft rubber tubes which compress readily in the wound, appears theoretically correct, although practically the circumstances are different. The rubber tubes of moderate firmness and elasticity are hard enough for the soft parts. Besides, a very great pressure effect must cautiously be avoided on account of the danger of decubitus. When a drainage tube fails in per-

formance of its function, the failure is always attributable to an entirely different cause.

The occlusion occurs almost invariably from thickened or coagulated products of secretion, and it is not due to compression of the tube and narrowing of its lumen in the wound. The hardening of the ordinary red rubber tubing in sulphuric acid (Javaro, 1888) appears therefore to be superfluous.

It must be admitted that the glass tubes are easiest and best maintained aseptic, although there will be found no difficulty in this regard with the rubber drains. Here it is also important to remember that a single boiling or repeated sterilizations in soda solution or hot water will be tolerated by the gum articles, and that by boiling for five minutes all the bacteria which come into question are destroyed. So also may the drainage tubes be sterilized in steam in fifteen to twenty minutes. For preserving them in a condition of sterility, they should be submerged in a strong antiseptic such as a 5 per cent. carbolic acid solution. Corrosive sublimate is not adapted to the purpose, as it enters into combination with the rubber and becomes precipitated. The carbolic acid in which the tubes are placed must be renewed from time to time. Before using them, they may again be sterilized for a few minutes in the soda as a matter of extra precaution.

The tube is fastened in place by means of a sterilized silk thread, with which it is tied or sewed to the edge of the wound, or a pin may be used for this purpose—preferably, a safety pin. The latter are boiled in soda solution, then dried and preserved for use, or they may be placed in absolute alcohol in sterilized receivers. Just prior to insertion they are again submerged in the boiling soda.

If it is desired to utilize the principle of capillary attraction, it is not necessary to employ such materials as glass, wool, or horse hair, as we have in the presence of gauze, ever now at

hand, an article which absorbs and dissipates fluids admirably, and which as a dressing previously sterilized is available. A strip of gauze laid in the tract of a wound, will, to say the least, be as serviceable as any of the materials above enumerated, which can never be used without troublesome preparation.

CHAPTER X.

ASEPTIC SPONGES AND ABSORBING PLEDGETS.

The Importance of Asepsis in Absorbing Pledgets—The Better Material for Sponging is Gauze—Cheaper Substitutes—Sponges—Danger of their Application—The Indispensability of Sponges in Certain Operations—Methods of Disinfecting Sponges—The Disfection by Means of Soda Solution.

SURGEONS who desist from irrigation of wounds, during and after operations, should be provided with an aseptic material, with which blood and pus may be absorbed and removed. None the less important is this requirement for an article which can be used in the temporary compression and tamponing of wounds. Naturally the material used for this purpose must absorb well the fluid products and possess coherence sufficient to prevent filaments and particles from remaining in the wound. We have in absorbing gauze an article which fulfils all these requirements. It may readily be sterilized and is pressed into pledgets composed of pieces 20 cm. square. The quantity of this material which is used in case of a bloody operation is naturally large, as each pledget can only be applied once and the employment of this ideal article for sponging is often very expensive. A somewhat cheaper substitute is found in small bags filled with moss or wood wool. These materials, the gauze pledgets and the small bags, with the remainder of the dressing outfit, are sterilized for thirty minutes in the steam chamber and destroyed after each usage.

In a technical sense sponges are undoubtedly preferable; their enormous absorptive propensity, their elasticity and pliability, are unexcelled. Upon grounds of asepsis, however, their application has certain objections. Their sterilization is attended with great difficulty—a subject to which we will presently refer. An important point to be considered is the expense, especially of a good material. This is so great that the distruction of the sponges after each operation can not well be contemplated. Consequently the same sponges must frequently be used in a whole series of surgical procedures.

As a rule, only a limited number of sponges are used in an operation, and these whether saturated with pus or blood are washed, dipped briefly into the antiseptic, and handed again to the operator. Sponges are only effectual when moist, and cannot be used dry like the gauze pledgets and moss bags.

The miscellaneous employment of the same sponges in varied operations adds greatly to the danger of infection and must be regarded as more or less hazardous. We should economize rather in the external dressing, than in the material used for sponging, the aseptic cleanliness of which is of such great importance, by reason of its direct contact with the wound. When it is at all possible we should employ sterilized gauze as best and bacteriologically safest, and restrict within convenient limits the use of the sponges. The latter, however, cannot be absolutely dispensed with. In case of large operations about the oral cavity, in resections of the upper jaw, in urinoplasties and also in laparotomies, for absorbing, plugging, and for temporary tamponing of the wound cavities, sponges have no substitute. Some practitioners have regarded the disinfection of the sponges as a very easy matter. Kümmel thought that by washing them, even saturated with purulent matter, for three or four minutes in water and soap, then laying them for one to two minutes in 5 per cent. carbolic

acid, in chlorine water, or in 1 per cent. corrosive sublimate solution, they would no longer contain live and concealed bacteria. This we now know to be incorrect. That the sponges are not readily sterilized is, a priori, in accordance with their enormous power of absorbing pus, blood, and all forms of infected fluids.

Practitioners have always found this to be true in that they have not obtained satisfactory results from such a simple sterilization. Submersion for at least weeks in strong antiseptic solution would be necessary. The fixed-day system is much employed, and the visitor to a clinic at which the sponges are still in use, will often observe large receivers containing the sponges, upon which is printed in capital letters the name of a week day. This is a very practical device. The compartment for each day of the week contains only the sponges needed for that day. After use in an operation the sponges are thoroughly washed, and then placed in 5 per cent. carbolic acid solution, or in a solution of 1 : 1000 corrosive sublimate. Here they remain for a week. It is true that much more is accomplished by a submersion for eight days in a strong germicidal solution than by one of a few minutes. In a measure this method of disinfection may suffice, but it cannot be regarded as absolute. We know, for instance, that anthrax spores, after being subjected to the action of a 5 per cent. carbolic acid solution for fourteen days, may still remain uninjured, and that ordinary vegetative bacteria, when enveloped in fat, tolerate sublimate solution for eight days. Permanganate of potash is much in vogue for disinfecting sponges. Here the sponges are first washed thoroughly and then placed for 24 hours in a solution of 1 : 500 of this substance, after which they are decolorized in a 1 per cent. solution of subsulphate of sodium, to which is added 8 per cent. of pure hydrochloric acid. They are then rinsed in water and pre-

served in a 5 per cent. solution of carbolic acid. This truly complicated disinfection is not absolutely reliable. Fritch found by investigations in the Billroth Clinic that 20 per cent. of the sponges thus prepared still contained bacteria. The fact need not surprise us, as the method is not superior to the use of carbolic acid and corrosive sublimate. We would be relieved of all embarrassment if we could sterilize the sponges in the ordinary manner by means of heat, but these articles can neither be boiled in water nor steamed in the sterilizer ; they shrink during these procedures and become very hard.

Only by means of dry heat can the sponges be rendered aseptic. Benkisser was the first to apply this method. He placed the sponges in a hot air sterilizer and heated them for a number of hours at 140° to 150° C. This can be done, however, only when the sponges are entirely free from fluid. In presence of moisture they shrink and become indurated. The sponges must therefore be absolutely dry before disinfection, and heated very gradually to the higher temperature, in order that the atmospheric moisture will be dissipated before 100° is reached. This necessity of absolute dryness reduces greatly the practical worth of this otherwise valuable method, and renders it inapplicable for the majority of physicians. The following procedure of the author is simple, and is more certain than any of the foregoing. The sponges are first freed of gross dirt. If they have never been used the sand and shells must be removed by beating them thoroughly. They are then soaked for long intervals in cold water, and alternately compressed and allowed to refill. Always after usage the sponges are cleansed as thoroughly as possible by washing them first in cold then in warm water.

They are then pressed out and wrapped in a linen towel, or, better still, placed in a special sack. The latter is submerged in a boiler of the largest permissible size con-

taining hot soda solution—1 per cent. As previously stated, the sponges will not tolerate boiling; this causes them to shrink, consequently the reservoir must be removed from the fire before the sponges are put into it. Complete asepsis is insured by submersion in the boiling lye for 20 to 30 minutes. The sponges, still contained in the sacks in which they have been sterilized, are freed of the soda within them by washing in sterilized water—alternately compressing them and allowing them to refill. After this they may be preserved in antiseptic solution—preferably corrosive sublimate, $\frac{1}{2}$ per cent. Carbolic acid is less adapted for the purpose, as it causes intense browning of the sponges. Sulphuric acid should not be used for the previous bleaching, as it causes the sponges to take on a blackish discoloration in the corrosive sublimate subsequently. After impregnation with resistant anthrax spores and pus, according to investigations made by the author, sponges were rendered sterile in ten minutes by the boiling soda, so that a submersion for forty minutes must answer fully. This result is dependent upon the fact that the soda lye, after its removal from the fire, retains a temperature of 80° to 90° for a long interval, and this temperature suffices to destroy anthrax spores quickly (Behring). By resorting to this method frequently, however, the sponges gradually become impaired, losing their elasticity, but it must be conceded that after use a number of times a sponge merits destruction, to be replaced by a new article.

In use of the sponges it is important to remember, for those who will operate aseptically, first, that they can only be used moist, *i. e.*, when dipped in a sterile fluid; and, secondly, that they always retain some of the antiseptic in which they have been preserved.

CHAPTER XI.

ASEPTIC INJECTION AND PUNCTURE.

Infection Following Hypodermatic Injection—Many of the Hypodermatic Solutions most commonly Employed Contain Myriads of Micro-Organisms—Prevention of the Development of Bacteria in these Solutions—Disinfection of Syringes—Boiling—The Construction of Syringes—Disinfection of Needles.

In consequence of the extended use of hypodermic puncture, the injection of substances into affected organs, and the aspiration of pus and other fluids for diagnostic and curative purposes, it is necessary to enter into a detailed consideration of the aseptic requirements for these procedures.

In the injection of joints, the puncture of hæmatomas, and similar operations, the strictest aseptic precautions are demanded, greater naturally than for ordinary hypodermic injection. The impune neglect of antiseptic measures in the enormous number of these daily injections might make it appear superfluous even to think of utilizing such procedures. The comparative infrequency with which infection occurs is dependent in part upon the fact that the seat of these injections, the subcutaneous cellular tissue, affords relatively unfavorable conditions for an infection through the syringe, the admitted fluid rather tending toward dissemination by rapid absorption, and not being allowed to accumulate locally. These conditions are modified, however, when materials are injected which are difficult of absorption, and which by damaging the tissues predispose to infection, as is evidenced by the frequency with which abscess occurs after the injection of

calomel, oleum cenereum, (oleate of mercury 1 part in almond oil 10 parts), etc. They are modified also when instead of a comparatively robust individual one cachectic and inclined toward infection receives the injection.

The presence of multiple abscesses in the body serves often as a guide in the diagnosis of severe cases of morphiomania, and to the pathological anatomist innumerable pus accumulations in individuals having died from cancer is not an uncommon observation, and is a plain indication of the frequency with which morphia injections had been resorted to by the person in relief of his misery. Severe, even fatal cases of infection from hypodermic injection are known to us. Bouchard relates the following facts : A morphine fiend in his clinic, acting in the capacity of nurse, suddenly was attacked with severe erysipelas, and upon close investigation the cause was found to proceed from a hypodermic injection which the individual had made with a very unclean syringe. In the evening the ward physician gave the attendant affected with erysipelas a hypodermic of morphia with an ordinary syringe and, cleansing the instrument only superficially, used it again before completing his visit in administering injections to four tabes cases. After two days all four were attacked with severe erysipelas, which started from the seat of injection and led to the death of three of the patients.

In the year 1882, in the Charité, Berlin, as reported by Brieger and Ehrlich, two typhoid cases were treated with injections of tincture of musk to counteract symptoms of collapse. In both cases the same solution and the same syringe were used, and in both, starting from the point of injection, a severe purulent œdema developed which led to a rapid death. Two cases of fatal phlegmon after the subcutaneous injection of quinine have been reported by the Russian military physician, Herschelmann.

The transmission of anthrax, by hypodermic injection, has been observed in the Breslau Clinic of Dermatology. Here, after the subcutaneous injection of arsenic, four patients became affected with anthrax œdema, more or less severe, starting from the point of injection. The arsenic solutions were free from bacteria, and Jacobi, who made a very careful bacteriological study of the cases, concluded that the first of the four patients was inoculated with the injection, and that from this case the others were infected through the syringe.

Two cases are indeed known in which tuberculosis has been conveyed by subcutaneous injection. One has been reported by König, the other by v. Eiselsberg.

In an injection we have to consider as possible sources of infection :

1. The skin of the patient.
2. The fluid injected.
3. The syringe.

When the skin is reasonably clean the danger of infecting the patient with the syringe, by the bacteria of the surface being carried into the interior, is, naturally, not great. A special disinfection of the skin for an ordinary hypodermic injection may, in fact, be regarded as unnecessary. In the injection and puncture of large joints and similar procedures, the method outlined in Chapter V. should be practised.

To the subject of asepsis in hypodermic fluids there has in general been too little attention given. Many of the solutions commonly employed contain bacteria when obtained from the apothecary, and in course of their usage they become more contaminated. We have made extended investigations (the author and Hohl) in the von Bergmann Clinic, with the view to determining the bacteriological condition of solutions obtained from various apothecary shops in Berlin, as well as of those used in the clinic itself.

One per cent. muriate of pilocarpine solution was found in the course of these investigations to contain innumerable bacteria. The ordinary ergotin solutions showed approximately 10,000 per cb. cm. Other solutions observed to be very rich in micro-organisms were: atropia, 1 per cent.; morphia muriate, 1 per cent.; and muriate of cocaine 1 per cent. The 1 per cent. morphia solutions used in the wards of the Royal Surgical Clinic, preserved in vials with glass stoppers and renewed every six to eight weeks, were found by repeated tests to contain always 200 to 300 germs per cb. cm. Iodoform glycerine (10 per cent.), camphor oil (1:10), hydrochlorate of apomorphia, quinia bisulph (1:10), antipyrin, (5:10), the mercury combinations, and also the stronger concentrations of some of the above-named drugs—for instance, the 10 per cent. cocaine solution,—revealed very few or no bacteria. It is very important to determine to what extent germs which gain access to the hypodermic solutions can maintain their vitality or multiply, for, as we may readily understand, the danger is very great if, for instance, the pus-formers or the erysipelas streptococci present in a solution can develop into luxuriant, pure cultures.

Investigations have been made in this direction by Ferrari, and we have also given the subject our attention. The experiments consisted in making small inoculations of the staphylo and strepto-cocci into sterilized solutions; then by the Koch plate method it was determined whether the bacteria die or increase in number. Ferrari's results show that the germs of ordinary pus (staphylococcus pyogenes aureus) die at once in ether, tincture musk, and in saturated solution of quinia. In 10 per cent. cocaine solution they existed for over two hours. In 2 per cent. morphia solution they do not die for twenty-four hours. In glycerine the staphylococci continue to live for six days; during this time they gradually lose their viability.

In distilled water, in 1 per cent. atropia solution, and in ½ and 1 per cent. morphia solutions the organisms not only remain alive for weeks, but indeed multiply to enormous proportions. Our own investigations, which were similar in extent to those of Ferrari, gave very closely corresponding results. Ten to twenty per cent. quinia bisulphate solutions destroyed staphylococci in a very short time, as did also 50 per cent. antipyrine and 20 per cent. benzoate of caffein. In nitrate of strychnia (0.15: 30.0), the bacteria maintain themselves for eight days; in 1 per cent. hydrochlorate of cocaine, after longer intervals than eight days, thousands were still present; in 1 per cent. atropia and 1 per cent. morphia solutions the numbers increased. These investigations in the laboratory correspond with what is above described as having been found in practice, in that the solutions which are here shown to be especially susceptible to the development of germs, or which permit of the bacteria maintaining themselves, are also those which our experience has usually revealed to be rich in microorganisms. These solutions (the ones most commonly employed) require especial precaution in their use.

Following is their classification :—

Solutions which are very rich in bacteria or may become so:

1 per cent. solution sulphate of atropia.
1 " " muriate of morphia.
1 " cocaine solution.
1 " pilocarpine solution.
solutions of ergotin.

The importance of these investigations pertains especially to the cocaine solutions, used so extensively at the present time in minor surgical practice, for, of what avail are our antiseptic precautions in an operation, when for the induction of anæsthesia we inject thousands of pus-formers under the skin?

The necessity of sterilizing the hypodermic solutions is to-day very obvious.

The fluids which destroy the bacteria directly, or possess the property of actively counteracting their development, are easily enumerated. A few—for instance ether, alcohol, concentrated solution of iodine, corrosive sublimate, and the stronger solutions of carbolic acid, etc.—by their inherent antiseptic properties, exempt us from special precautions regarding them ; others—for instance iodoform glycerine or idoform oil—are, with the unfavorable conditions which they afford for the nutrition of bacteria, by a single sterilization reliably placed beyond further annoyance to us for a long interval, if the necessary subsequent precautions for avoidance of contamination are observed. The single or, in special cases, frequently repeated sterilization is here best effected through steam, in which the vial containing the iodoform emulsion is placed for an hour.

Iodoform in glycerine or oil at 100 ° C remains unaltered ; at least after injection of glycerine emulsion so treated we have never observed any harmful effects or toxic iodine symptoms. Von Stubenrauch contends that it is important to allow the vials in which the emulsion is being sterilized to remain open. In closed flasks iodine is easily liberated at 100 °.

Where a steam sterilizer is not available the oil may be boiled, the vial asepticized by boiling, washed with sublimate and ether, and then the emulsion prepared by adding the powdered iodoform (Garre). But here the iodoform is never sterilized, and it may contain bacteria, hence this procedure is not devoid of the possibility of error. Böhm's method of first washing the iodoform with aqueous sublimate solution is preferable. In response to the suggestion of von Stubenrauch, to employ a mucilaginous solution in preparing iodoform emulsion 5 (per cent. sol. acacia, 180 parts to 20 parts alco-

holic solution of iodoform), we would state that solutions which contain organic substances that are favorable nutrient media for bacteria are always more difficult of sterilization and of being maintained sterile than a glycerine emulsion.

Böhm has observed that iodoform dissolves in oil of sweet almonds up to 5 per cent., and forms an amber yellow fluid very well adapted for injection. This we can substantiate, but have retained the glycerine emulsion because we could desire nothing better.

It is more difficult to maintain asepsis in the above classified hypodermic solutions which favor the growth of bacteria that have gained entrance to them, and which are even a more or less favorable culture medium for micro-organisms. A reliable means of avoiding infection with these solutions would be to boil them each time before using them, although this is too exacting, and might, by its frequent application, induce chemical changes. These solutions must naturally be preserved tightly closed, and too large quantities should not be prepared in advance; then by the addition of agents which prevent the development of bacteria, the aseptic conditions should be artificially maintained.

As an antiseptic to be added camphor has been recommended, although on the basis of bacteriological tests we cannot indorse this suggestion. Camphor is only slightly soluble in water, and works very ineffectually in limiting the development of micro-organisms, whereas creosote, carbolic acid, and corrosive sublimate, in small quantities, are very well adapted for the purpose. Most effectual is carbolic acid, already made use of in practice, and we would regard the customary addition of two or three drops to 30 cb. cm. of the hypodermic solution as sufficient. Any injurious effect from the carbolic acid is excluded by this degree of dilution.

Very difficult of being maintained cleanly are the syringes,

and an especial hindrance to thorough sterilization is offered by the piston of the ordinary instrument. R. Koch, in his syringe now quite universally known, has obviated this difficulty in a very ingenious manner, in that he entirely dispenses with a piston and utilizes the air in a rubber bulb to expel the contents of the barrel.

FIG. 31.
KOCH'S SYRINGE.

As shown by Fig. 31, the syringe consists of a graduated glass cylinder, into one end of which is fitted the canula, and to the other end the rubber bulb. A stop-cock closes the communication between the bulb and the glass cylinder. Although this syringe may be an ideal aseptic instrument, it does not conform to the requirements of the majority of practitioners. The general use of the syringe in practice is precluded by the difficulty which its use offers in the aspiration of fluids, and in the injection of thick, oily substances.

Syringes, the construction of which is based upon similar principles—for instance, the one of Strohschein,—have very similar disadvantages. We have not been convinced that the piston syringe can be dispensed with ; its construction, furthermore, has been markedly improved in later years. To establish a standard for the sterilization of syringes we infected (after asepticizing them completely by boiling), piston instruments, such as the syringe of Overlach, with the germs of ordinary pus and of green pus (staphylococcus pyogenes aureus and bacillus pyocyaneus), by aspirating into the syringes pure bouillon cultures and pus itself ; we then endeavored to disinfect the instruments. The simple, repeated through injection of sterilized water—the mechanical forcing in and out of the

same,—as shown by these experiments, is only of little value, The number of bacteria in the syringe becomes less, but after ten through injections of water there still remain thousands of bacteria. Of other agents we then tried 3 per cent. carbolic acid, ½ per cent. corrosive sublimate, absolute alcohol, and boiling water. The best results, as we might have supposed, were obtained by the thorough injection of boiling water. After repetition of this expedient five times the syringes were sterile. Next to the boiling water absolute alcohol worked most effectually in destroying the pus-formers, and the least influence was exerted by the 3 per cent. carbolic acid solution. After aspirating in and expelling the latter ten times there were still present over 5000 bacteria.

From these results we should endeavor to have the construction of the piston syringes such as to permit of their being boiled, as this remains the most reliable means of disinfection.

The hard-rubber attachments and leather washers are to be avoided; for the barrel of the syringe glass or metal should be chosen, and for the piston bulb a material which readily tolerates heating to 100° C. The syringes devised by Overlach, Meyer, and Roux, fulfil these requirements as regards the small hypodermics.

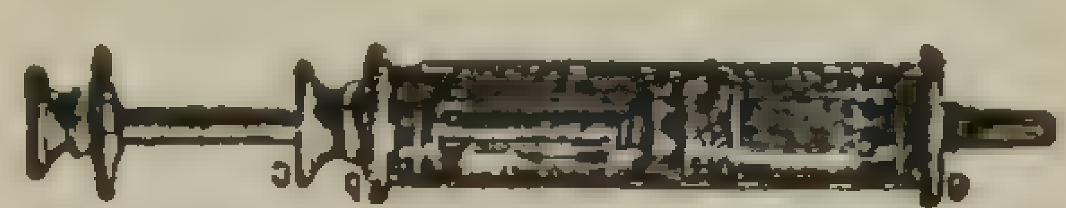

FIG. 32.
OVERLACH'S HYPODERMIC SYRINGE.

The syringe of Overlach, Fig. 32, consists of a glass cylinder, the mouth-piece and plunger of which are separated by means of a vulcanized rubber ring with screw arrangement. The latter, even after frequently repeated submersion in boiling water remains uninjured. In the Meyer (Fig. 33) and the Roux syringes, the mouth-piece is melted from the glass cylinder.

In the Overlach and Meyer syringes the piston is made of asbestos, in the Roux instrument from elder-pitch. In the Meyer and Overlach instruments the piston regulation conceived by H. Hausmann is utilized. This consists in the compression of the bulb between two *metal plates* attached to the central rod, which causes close adjustment of the bulb to the glass barrel.

FIG. 33.
MEYER'S HYPODERMIC SYRINGE.

The asbestos piston bulbs have the disadvantage of loosening in texture in their continued use and thus fitting less tightly; they allow particles to become detached which gain access to the hypodermic fluid. This is particularly true of large syringes of 40 to 100 grammes' capacity. In their construction asbestos has thus far been inapplicable.

By an ingenious use of linoleum, Baumgartel of Halle has been able to obviate the above difficulty and manufacture syringes of any size which may be boiled.

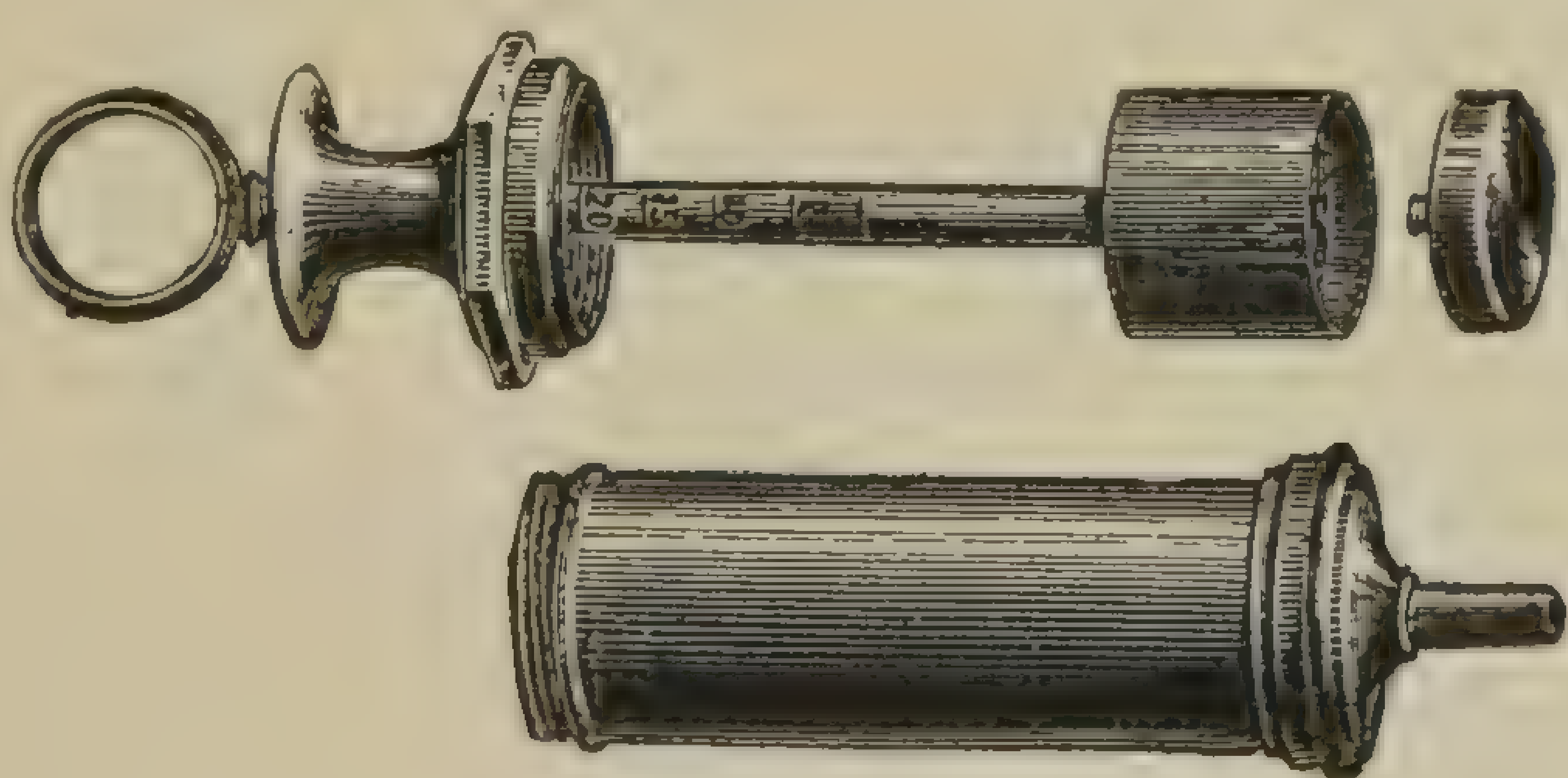

FIG. 34.
SCHMIDT'S SYRINGE.

These syringes, like Hausmann's, have an asbestos bulb, compressible by means of a screw in the piston-rod, but are provided in addition with a linoleum plating over the two surfaces in the lumen which approximate. The glass cylinder is imbedded in metal, and upon each end linoleum washers are

adjusted instead of the leather formerly employed. This syringe has proved satisfactory in von Volkmann's and also in von Brammann's and in von Bergmann's clinics.

Instruments in the construction of which glass, metal, and other articles are used frequently break when boiled owing to the unequal expansion of the different materials. This danger is present in Baumgartel's instrument, which must be heated with great precaution and cooled gradually to avoid the glass cylinder becoming cracked.

Schmidt, of Berlin, recently began the manufacture of an instrument made entirely of metal (Fig. 34). From our own experience we are assured that this syringe conforms to all the requirements of an aseptic instrument, with the single objection of being non-translucent. The cylinder is composed of nickeline, and the piston bulb is made from a thin, elastic, concave piece of nickel which fits closely to the walls of the barrel. The free passage of the surfaces over one another is facilitated by a light smearing with Sarg's glycerine. Oil is avoided. The syringe is always ready for use, and is not damaged by boiling.

We will not enter further into detail here (this information, however, is important to physicians), and refer to another syringe which up to the present time has been used principally for 1 to 2 c.c. injections. Attempt has repeatedly been made to construct syringes in which the leather piston bulb is retained, but contact of the fluid with the piston or the cylinder avoided by having it contained in a separate receptacle (Beck, Liman, and others). It is, however, difficult to avoid absolutely the entrance of fluid from this sub-compartment into the barrel, and *vice versa*. Reinhardt devised a syringe, upon the piston-rod of which a new cork bulb could be screwed for use in each injection. Farcas employed a rubber ring in the endeavor to procure perfect fitting of the bulb.

The most effectual method of sterilizing needles is by boiling them in water or, still better, in soda solution. They should, therefore, be made entirely of metal. The needles can be heated in the flame only when composed of platinum-iridium. Steel needles are at once rendered useless by red heat on account of the softening which the steel undergoes.

CHAPTER XII.

ASEPTIC CATHETERIZING AND SOUNDING.

The Germs of Urinary Decomposition in the Bladder—The Normal Urine in the Healthy Bladder is Free from Germs—In Decomposed Urine Bacteria are always Found—The Occurrence of Infection—Disinfection of the Instruments—Metal Instruments—Gum Instruments—Catheters and Bougies with Lac Coating—Bacteria Contained in the Urethra—Disinfection of the Urethra.

NOTWITHSTANDING that Pasteur in the year 1860 discovered that the decomposition of voided urine in contact with air is dependent upon the development of bacteria, and that the inflammations within the bladder have a similar basis, our knowledge of these changes in the urine is still very imperfect. Indeed, it appears less firmly established to-day than after the investigations of Pasteur, as then it was a particular bacillus, "une torulacee en chapelets de tres petits grains," which external to or within the urinary bladder has the effect of producing peculiar ammoniacal decomposition of the urine.

More recent and deeper researches have shown that here more than one micro-organism is active. Rovsing demonstrated through exact bacteriological experiments that staphylococci and streptococci, which he identified with the well-known pyogenes, are the frequent cause of cystitis, and according to observations made by Schnitzler, of twenty cases of purulent bladder inflammation, thirteen were attributable to a certain organism which this investigator named urobacillus pyogenes septicus. Krogius has recently observed that

the bacillus coli communis and the proteus vulgaris (Hauser) have a very important etiological relation to cystitis. At all events, the bacteria which produce ammoniacal decomposition in voided urine, and which are usually comprised under the common name, micrococcus ureæ, are not the same as those which play a rôle in cystitis. The former often come from the atmosphere, and many of them cannot develop without the presence of air; while in the bladder, according to the investigations of the physiologists (Planer and Pflüger), no free oxygen is present, and only the so-called anaërobic bacteria can live.

Two facts are firmly established.

1. That the normal urine in the normal bladder is always free from bacteria.

2. That in the decomposition of the urine within the bladder bacteria are always found.

Various investigators have proven the absence of micro-organisms in the bladder (Pasteur, Lister, and others), and we will here only refer to the ingenious experiments of Cazeneuve and Livon, who induced retention of urine in dogs by ligating the prepuce. After the bladder became filled, the ureters and urethra were ligated and the bladder extirpated, and the organ kept for a time in ordinary room temperature, then in an incubating chamber was preserved for long intervals, without the occurrence of decomposition of the urine, which latter, under the circumstances, would not have remained absent were micro-organisms present.

This is not the place to elaborate upon the manner in which microbes gain entrance to the bladder, which can produce in the patient such grave urinary changes—to discuss to what degree a descent from the kidneys, an import through the urethra, etc., comes into question. Sufficient for our purpose is the very common experience, that after the introduction of

instruments through the urinary canal into the bladder, especially catheters and bougies, severe bacterial infection occurs with such extreme frequency as to demand a most scrupulous asepsis in the manipulation.

A catheterization cystitis is not an infrequent clinical picture, and every practitioner can recall cases in which, after a single performance of the operation or repeated catheterizations with unclean instruments, he has observed the development of a severe vesical inflammation.

It has been repeatedly determined experimentally that in animals bladder infection with pathogenic bacteria is not easily induced if the genital tract is completely normal, and there is a freely voided urine which can wash out the agents of infection that have been introduced, and that it is much more a pathological moment, as a retention of urine, an injury, or some such condition, that is required for the origin of a cystitis. Still these requirements are not constant, and Schnitzler was able with his urobacillus pyogenes septicus, through simple rubbing of pure cultures into the healthy bladders of animals, to induce severe infection.

This argument is, furthermore, of only secondary practical importance, as healthy bladders are seldom the objects of disturbance by our instruments, and, as a rule, there is presented just the pathological condition which favors an infection.

The instruments which we find it necessary to introduce into the bladder are made

1. Of metal.
2. Of rubber.
3. Of spun silk or cotton with lac coating.

Referable to the disinfection of these instruments, it must be borne in mind that always in using them they are covered with fat or oil for the purpose of rendering them slippery and more readily introducible through the urethra, and that

this fat, as we have heretofore repeatedly revealed, affords a protective medium for micro-organisms. Here it is not sufficient for disinfection to simply immerse the instruments in some weak solution, as is still frequently to be observed ; on the contrary, an energetic sterilization is imperatively demanded.

The metal instruments, whether bougies or catheters, are very easy of disinfection by simply boiling them before each operation, as described in Chapter VI. They are also readily maintained aseptic without becoming damaged, by submerging them in carbolic-glycerine or alcohol. Of especial importance for their cleanliness is a thorough rinsing, washing out, rubbing, and drying after each usage.

More difficulty is experienced in the cleansing of the rubber instruments, the so called red Nélaton catheters. They permit, however, very readily of disinfection a few times in steam, hot soda solution, or boiling water. In long-continued daily use they must be constantly submerged in strong carbolic acid or renewed sublimate solution, then before introduction they should be washed with sterilized gauze or rinsed in sterilized water to remove the antiseptic which is very irritating to the urethral canal.

The ordinary lac-coated instruments are very difficult of disinfection. They do not tolerate well either boiling or steam sterilization, and still less heating in dry air. Even a long submersion in the antiseptic solutions, carbolic acid or corrosive sublimate, renders them useless. For this reason, Albarran devised an instrument with a caoutchouc coating which withstands both boiling and long submersion in sublimate solution. These caoutchouc catheters have not, however, as yet been used very extensively.

It is very important to know that mechanical cleanliness, the active rubbing with a sterile gauze pledget and warm

water or sublimate solution, suffices for a plain bougie or catheter. The author has experimented especially with these red lac-coated bougies, infecting them with pure cultures of various bacteria and then rubbing them actively. The rubbing for a minute with a wet pledget, and subsequently with dry gauze, answers practically always to render the previously infected instruments aseptic.

To cleanse the lumen of the catheter, warm water, warm corrosive sublimate or carbolic acid solution must be energetically passed through it. Farcas has devised a steam apparatus, consisting of a small water kettle with a tubular extension to which the catheter is adjusted. The water in the kettle is heated to boiling by means of a spirit lamp, and the steam generated passes up the extension tube and streams forcibly through the catheter. This apparatus naturally cleanses, more thoroughly than the injection of the instrument with solutions.

It is an unfortunate fact that in catheterizing, as in sounding, we must always pass through a bacteria-enriched canal, the urethra, in getting into the bladder. According to concordent researches by Lustgarten and Mannaberg, and also by Rovsing, there are always present in the normal urethra vast numbers of organisms, and in some instances such as are capable of producing urinary decomposition. These organisms make their presence noticeable in a very unpleasant manner when we introduce a temporary catheter. The latter may be required to remain even for a day. Then the increase and damaging effect of the urethral flora never fails to manifest itself, and urethritis and vesical catarrh are almost invariable consequences. For a singly executed or very frequently repeated catheterization, the danger of infection, as far as threatened by the bacteria in the urethra, is however, not very great. To substantiate this we have the clinical

experience, that with perfectly clean instruments the catheterization may be performed without serious consequences. However the condition of the urethra in catheterization generally, demands the most particular attention and a catarrhal or a purulent inflammation are absolute contra-indications to the introduction of an instrument into the bladder. Under such circumstances, a puncture of the organ is to be given the unqualified preference where evacuation is demanded.

Always in catheterizing and sounding, the orificium urethræ must be cleansed, and if we will be especially cautious, the urethra should be irrigated with sterile water, aseptic chloride of sodium or boracic acid solution.

CHAPTER XIII.

SOLUTIONS FOR IRRIGATION AND WASHING.

Spring Water is Free from Germs, otherwise the Water on the Earth's Surface always Contains Bacteria—The Number of Germs Present is very Variable—Pathogenic Bacteria in Water—Sterilization of Water for Operations—Methods of Water Sterilization—Precipitation—Filtration—Boiling—The Addition of Antiseptics.

ACCORDING to the investigations of Carl Fränkel, water in the interior of the earth never contains any germs; so must the water which evaporates from the surface of the earth, to ascend, and condense into clouds in the higher, cold altitudes, also be free from bacteria, because the latter cannot arise from moist surfaces as already stated in Chapter II. Germs are likewise incapable of entering the air through the medium of vapor. When water from the interior of the earth reaches the surface, and the atmospheric moisture precipitates in the form of rain or snow, they are usually found to contain bacteria, as they have passed the contaminated strata of the earth in the one instance and of the atmosphere in the other and have taken up germs to a greater or less extent. In rain water, even during the precipitation, bacteria will be present, as the drops formed in falling absorb dust laden with micro-organisms, and well and spring water, aside from their contamination from the upper surface of the earth—the essential habitat of bacteria,—take up germs in their passage through pipes which it is difficult to keep clean.

It is very evident that water, which stands or flows on the earth's surface strewn with refuse and decomposed organic material of the most varied kind, must contain germs in great

abundance. The bacteria present in different waters fluctuate greatly, and from the few fission fungi per cubic centimetre contained in good well and spring water, there are found in contaminated streams, in drains and canals, often millions of mirco-organisms per cubic centimetre. In densely populated districts the rivers and brooks are to a high degree infected, and the color, consistency, and odor of many waters indicate that they deserve the name polluted rather than *water*, unqualified.

Popular sentiment has long since attributed to these polluted waters disease-producing potencies, and our present knowledge of intestinal mycosis reveals that not only cholera and typhoid fever but many other severe intestinal infections have a very close etiological relation to water. It is true that the greatest number of bacteria found in water belong to those which do not cause wound infection, but repeatedly some of the most virulent varieties have been present. In proof of this it is only necessary to remember that one of the most severe animal septicæmias, the so-called rabbit septicæmia, described by Robert Koch and Gaffky, is due to a bacillus which originated from the Panke, a stream flowing through Berlin. Rintaro Mori has isolated from canal water three pathogenic bacteria.

According to the investigations of Lortet and Despeignes the Rhone River of Lyons always contains pathogenic organisms, although only few other germs. These authors collected the bacterial residues from filters and injected them subcutaneously into guinea-pigs. The latter *invariably* developed a severe septicæmia and pyæmia which soon caused their death.

Repeatedly pyogenic staphylococci have been discovered in river and well water; with a knowledge of the dangerous characteristics of these organisms such water would be drunk

with hesitation. Tils frequently detected the germ of greenish blue suppuration, the bacillus pyocyaneus, in the hydrant water of Freiberg.

The quantity of bacteria which our waters contain, is in a measure dependent upon their character; upon the facilities with which they take up organic materials containing micro-organisms to dissolve them out and hold them in suspension; and to some extent the fact that water is naturally a favorable abode for germs, is determinative. The majority of bacteria can live for weeks and months in water, and for many germs the latter serves as a culture medium in which they multiply.

Bolton has shown that the presence of organic pabulem influences in a measure the number of organisms present, although certain bacteria increase rapidly in water containing comparatively little organic substance. The spontaneous proliferation of bacteria in quiescent water was recognized very early in hygienic investigations, and it was seen that for a quantitative analysis the examination must be made early.

Cramer found that Zurich hydrant water, after standing for a few days, increased 1700 times in its bacterial contents, and Leon discovered that fresh Munich hydrant water, which contained only 5 bacteria per cubic centimetre, after a quiescence of 5 days revealed 500,000 bacteria per cubic centimetre. Distilled water serves as a culture medium for certain saprophytes and permits their luxuriant growth. After distillation and sterilization of water, Bolton found that two common water bacteria when re-inoculated multiplied abundantly. This was repeated six times. According to Wolffhügel and Riedel, anthrax bacilli grow well in sterilized river water as well as in distilled water, and Giaxa has observed that they multiply also in sea water, as do likewise the pyogenic staphylococci of special interest to us.

At all events the pathogenic bacteria, particularly the germs of wound infection, remain active and capable of growth in water for long intervals. Strauss and Dubarry inoculated sterilized water, also distilled river and canal water with pathogenic bacteria, and found that in water in its natural state, as well as in distilled water, germs remain virulent for weeks, and in most instances for months. The duration of the viability of different organisms was found to be as follows:

Pyogenic staphylococci, 15 days.

Streptococcus pyogenes, 21 days.

Glanders bacillus, 57 days.

Tubercle bacilli, 115 days.

Uffelmann observed that anthrax bacilli lived in Rostock hydrant water for three months.

There is only one influence which renders difficult the existance of certain bacteria in water, and that is the conflict with other organisms—the battle of the germs among themselves. The pathogenic bacteria succumb rapidly to the better proliferating saprophytes (unless a large amount of organic material is present for their nutriment); they, therefore, live longer in water which is sterile.

We must conclude from these observations that water is essentially a germ-containing fluid, harboring often infectious bacteria, and that it must not be allowed to encounter fresh wounds without receiving some attention. This necessity for the sterilization of water must be given special prominence by reason of the fact, that irrigation with water taken from some convenient pond is one of the most widespread and pernicious customs in the treatment of recent injuries.

Hygienists have discussed the feasibility of having an especially purified water supply to cities for drinking and cooking purposes, aside from that used for general washing and cleansing. To-day the opinion is quite general that such

a separation of the water supply in every-day life is impracticable, and endeavor must be made to maintain the entire quantity in a state of the greatest possible purity. It is imperative that all water which encounters wounds, as in their irrigation, that used for irrigating the hands of the surgeon and the skin of the patient previous to and during operation, and the water employed in washing and scrubbing the skin of the patient with soap, should be sterilized.

For general cleansing purposes, washing of the operating room, the utensils, etc., the general hydrant supply, regarded as hygienically safe, answers.

The purification of water has been attempted in a variety of ways comprising the following:

1. Precipitation.
2. Filtration.
3. Destruction of the bacteria by use of antiseptics.
4. Sterilization by heat.

As observed by Cramer, bacteria tend to gravitate, so that in a quantity of water quiescent for a time fewer germs are present in the upper than in the lower strata and in the bottom. This precipitation of bacteria may be promoted by the addition of substances insoluble in water, which in settling carry down the organisms with them. These materials include sand, charcoal, coke, gravel, brick dust, clay, calcium carbonate, etc. According to von Krüger, the effect of such substances is in proportion to the slowness—up to a certain limit—with which the settling takes place, and the quantity added is also determinative. Water may be cleared by the use of precipitants and the number of bacteria perhaps somewhat reduced, but complete asepsis cannot be attained in this manner. This method is therefore inadequate for surgery.

Illustration of the working of filters is afforded us by nature. The absence of bacteria in underground water is dependent

upon the great filtering power of the earth, and this is evidence that by artificial means water may be purified perfectly. In the endeavor to imitate this process in nature we have, however, not as yet reached equal perfection in technique. The extensive sand and gravel filters used at the present time in many large cities are of some value, but they never free the water entirely of germs. The thousands of micro-organisms contained in each cubic centimetre of the Spree River water and the hundreds of thousands present in the Stralau are removed to a very great extent by the Berlin water-works at Stralau, although on an average about fifty to seventy bacteria per cubic centimetre are still found in the filtrate. The fact was established by Fränkel and Piefke that these sand filters are never an absolute safeguard against the presence of pathogenic bacteria artificially mixed with water; on the contrary, they readily allow a number of such germs to pass.

Even though all bacteria are removed by filtration from the main supply at a city's water-works, this would not insure its being germ-proof at the place where it is used. Having to pass through a system of pipes, the water is afforded many opportunities for re-infection. That this is true is proved by a comparison of the Berlin hydrant water with that just filtered at the central station in Stralau, in that the former always contains many times more germs than the latter. The *perfect* filtration of water in small quantities at the *exact place* where it is used is still for practice an unsolved problem. We may purify one or two litres in the bacteriological laboratory by passing it through dense porous cells. Here the Chamberland sand filters are very useful. But when we have to sterilize large quantities of water rapidly and reliably we must have recourse to some other means. The Chamberland-Pasteur filters, in which the water is aspirated through clay cells by the siphon action of a pending rubber tube, *filtres sans pres-*

sion (without pressure), rapidly deteriorate according to the investigations of von Kübler.

The quantity of water which these filters allow to pass, suddenly diminishes. For four days they work perfectly, but after this time there is a successive increase of bacteria in the filtrate. The pores first probably become occluded, and later micro-organisms grow through the filter. Recently *kieselguhr* (diatomaceous earth in which the organic matter has been destroyed by heat) has been used by von Nordmeyer and Berkefeld in the construction of filters which von Bitter has found to be very excellent. They have later been provided with an efficient arrangement for cleansing, consisting of two brushes which encircle the *kieselguhr* cylinder and remove all deposit, so that with proper attention governing their use they are very durable. These filters are, however, not absolutely reliable indefinitely. Thus far the purification of water by filters has not been sufficient guaranty of its sterility to justify its use in surgery. The employment of filtration for operative purposes would furthermore only be adapted to hospitals where more elaborate regulations are present. In private service it would not be practicable.

The sterilization of water for the preparation of washing and irrigating solutions in daily practice, leaves to our consideration only the application of heat and the use of chemical agents. Water may be boiled in steam in closed bottles, although this method is not practical. It requires a relatively long time; even small quantities—from two to three litres—heat very slowly in steam. A better way is to boil the water directly.

It has been shown in Chapter IV., that boiling water is our most powerful disinfectant, destroying highly resistant anthrax spores in two minutes. If we boil water for five minutes then it is sufficient for all surgical purposes. The germs which

resist this attempt at disinfection are non-pathogenic, and therefore it is unnecessary to consider them ; they would include such especially resistant organisms as the hay bacillus. We therefore regard the sterilization of water in expanded steam at 120° C., or boiling for an hour, for the destruction of

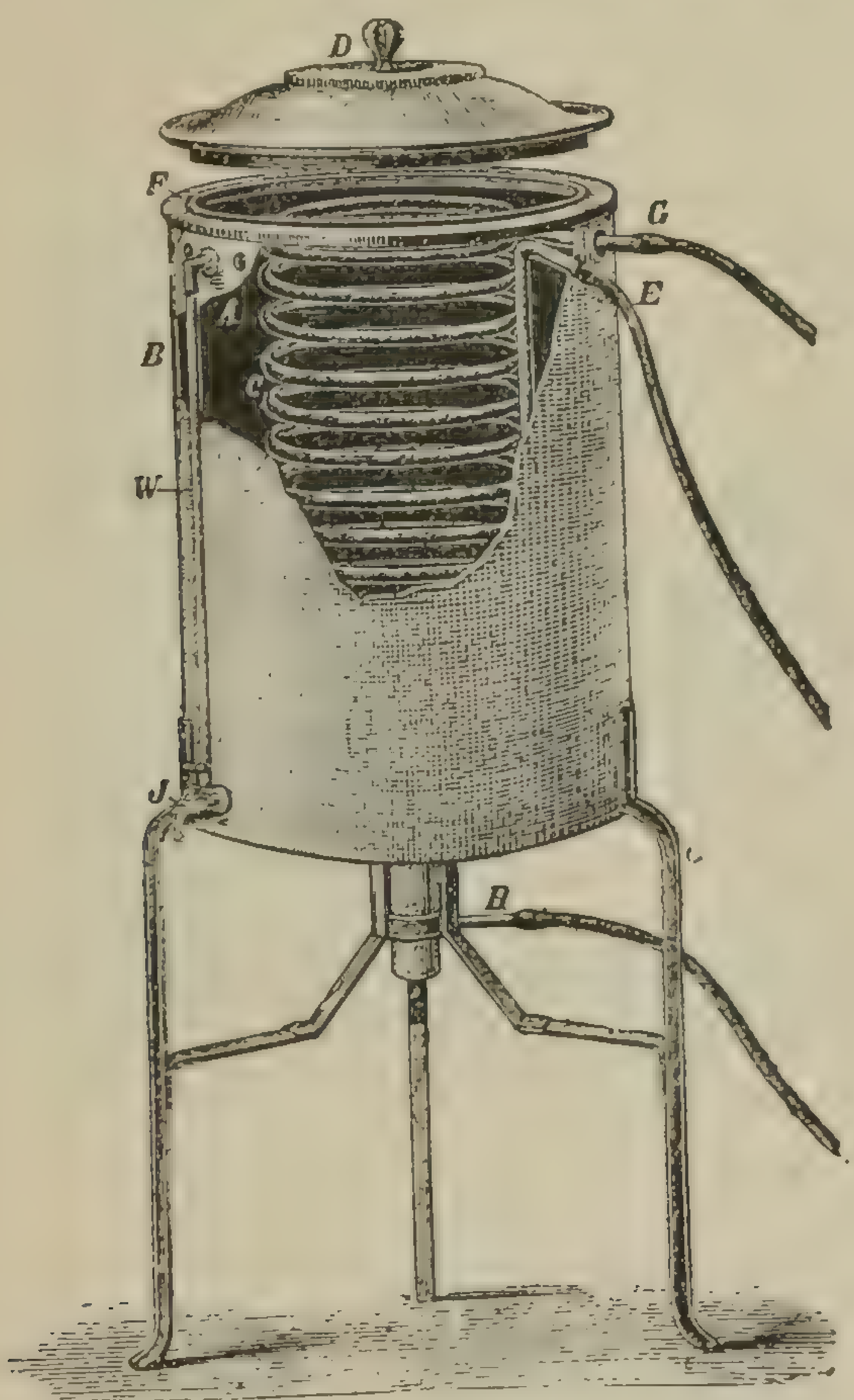

FIG. 35.

FRITSCH WATER STERILIZER.

The tank *(A)* is provided with a cover *(D)*. *J* is a faucet through which the boiled water is drawn off. *W* represents a gauge that indicates the contents of the reservoir. *H* is a large gas burner placed underneath the boiler. *C* is a coil of pipe, through which cold water enters from the hydrant at *G*, and escapes at *E*. The tank *(A)* is filled with warm water and rapidly boiled by gas supplied through the large burner *(H)*. After ten minutes the gas is turned off and cold water is allowed to flow through the central coil of pipe. Where steam is in use, instead of gas being employed the water may be boiled by having a steam pipe pass through the tank.

all bacteria, as recommended by Tripier, as unnecessary. The number of germs found in water rich in bacteria after boiling for a short time at 100° is very limited. According to Miquel, 95½ per cent. of all bacteria are thus removed. Rhone water, which was observed by Dor and Vinay to contain 33,000 micro-organisms per litre, lost through boiling all but 941, or over 96 per cent.

The certainty with which water can be sterilized by boiling, and the readiness of the application of this method, even in cases of emergency, commends its general use in surgery. A sufficient quantity of boiled water is the first thing to be provided in an operation. As water is a favorable culture medium for bacteria it is preferable to sterilize a fresh supply each time, although when asepticized by long boiling and preserved in bacteriologically safe glass jars, closed by sterilized cotton plugs, water will remain aseptic.

In general practice it will often answer to boil the water a number of hours in advance for operations, and preserve it in clean jars designed especially for this purpose. In hospitals a water sterilizer will be found useful.

Fritsch has devised an apparatus (Fig. 35) which merits approval. It consists of a tank in which the water is boiled by means of gas, and a central coil of pipe for conveying water from the hydrant to cool at once that which has been sterilized.

The majority of large hospitals constructed on modern principles have closed reservoirs containing water, which is boiled by steam from the boiler of the engine, that usually has a temperature much above 100° C., and are thus supplied with aseptic water which is distributed through pipes. This is the case in the von Bergmann Clinic, for instance. Where the heating is continued daily, and the supply replenished by allowing cold water to flow in gradually, these reservoirs scarcely ever

become cooled, and the water which traverses the pipes is continually aseptic ; usually it is hot or boiling.

Recently water sterilizers have been devised in Germany by Grove, and in France by Geneste and Herscher, in which by means of gas the water may be boiled before its exit from the hydrant. The water flows through a system of pipes over an intense gas flame, and is heated to 100° C., or higher. It is

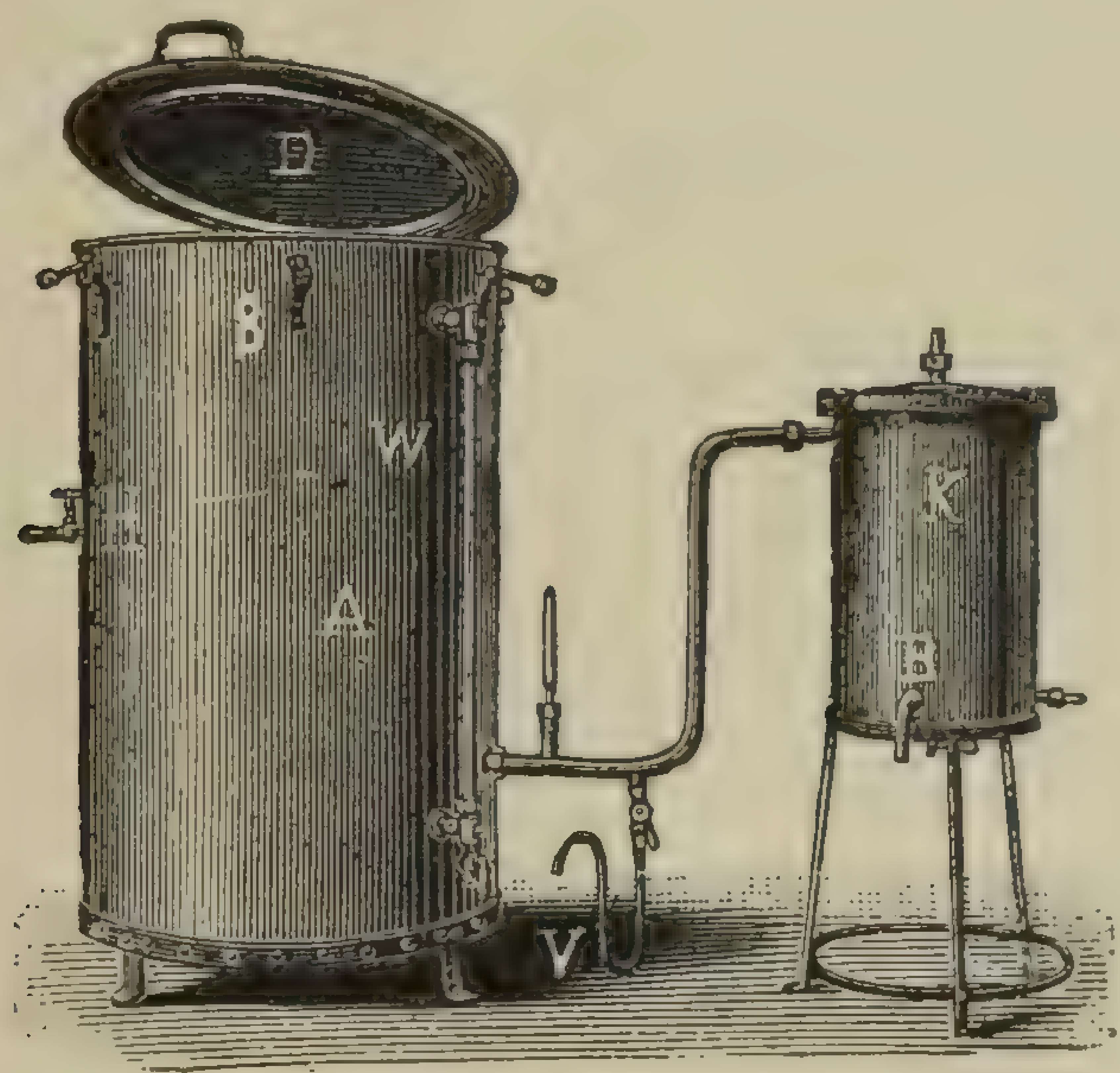

FIG. 36.

LAUTENSCHLÄGER STEAM STERILIZER.

Fig. 29 represents a Lautenschläger steam sterilizer (*A*), with discharge tube leading into a condenser (*K*), which is provided with a cold-water coil. At *B*, the steam, is drawn from the condenser as sterilized water.

then collected in a small reservoir, from which it is drawn through a pipe that is cooled by the water flowing through the hydrant, a twofold purpose being thus accomplished : the water going to the sterilizer is warmed, and that which has been sterilized is cooled. The quantity of water which may be rendered aseptic by this method is very large ; it is therefore inexpensive, and apparently a very promising device, but

we must await the trials of usage to see whether it proves practical.

Steam which has been employed for the sterilization of dressings may also be converted into aseptic water by condensation.

Simpler and in many respects more practical than boiling water, as a method of sterilizing it, is the addition of antiseptics. It might be supposed that this would be a very easy means of disinfection. In water which is bright and clear, the bacteria are isolated and not found in clumps difficult of permeation.

But in canals, ponds, and swamps, where water is contaminated by gross visible masses of impurity, harboring bacteria, which are perhaps pathogenic, reliable disinfection by this simple means is impracticable.

For purifying such waters, boiling should be resorted to, if the use of antiseptics cannot be preceded by filtration.

Mild germicides or the stronger agents diluted, which are never capable of destroying anthrax spores, cannot naturally render water germ-proof. One to two per cent. boracic, salicylic, or carbolic acid solutions must, therefore, when used in surgery, be prepared with sterilized water. An agent with which water may conveniently be asepticized for employment in the treatment of wounds is corrosive sublimate first introduced into surgery by Prof. von Bergmann. We know from the investigations of Geppert, however, that even in .01 and .005 per cent. solutions of bichloride, resistant anthrax spores may remain alive for over twenty-four hours. It follows then that these solutions should be prepared at least twenty-four to forty-eight hours before being used. Corrosive sublimate can markedly reduce the number of bacteria contained in clear water in fifteen to twenty minutes. This time is all that is necessary for destruction of the dangerous pus-

formers. Knowledge of this fact is very important in case of emergency, when sterilized water is not obtainable. Our ordinary waters are commonly heavily laden with alkaline earths, especially the lime salts, and these neutralize the sublimate. Bichloride solutions made with common well and hydrant water rapidly deteriorate, the mercury becoming precipitated in the form of insoluble compounds. According to Lieberich this is not a simple reaction, but rather there are a variety of combinations which enter into the formation of the whitish precipitate observed. This throwing down of sublimate may be prevented by the addition of acids, such as acetic or vinous, but better still by chloride of sodium. Lieberich states that Mialhe as early as 1845 noted that the decomposition of sublimate solution by the alkaline earths may be prevented by the addition of chloride of sodium or ammonium. We should in preparing bichloride add an equal quantity of common salt. Angerer has devised a tablet containing sublimate and chloride of sodium—1 gramme each.

One of these tablets suffices to antisepticize one or two liters of water, making a bichloride solution of .01 and .005 per cent. respectively.

The convenient form of this agent, and the readiness with which it can be applied in the disinfection of washing and irrigating solutions and in rendering other fluids antiseptic, has made its adoption almost universal in surgery.

An objection which has often been raised to the extensive use of bichloride is the danger of poisoning through want of proper precautions by the patient or attendant. Contrary to this objection, there remains the fact that with reasonably careful handling such grave consequences are not observed, and in the von Bergmann Clinic, where sublimate solutions have been employed extensively for many years, no case has occurred for complaint. The use of sublimate is justifiable,

however, only under medical control ; the drug should not be placed at the disposal of a layman. The physician must know the limits of its application from his pharmaceutical studies. He must realize that in the use of corrosive sublimate upon mucous membranes and large wound surfaces, great precaution is necessary. To distinguish the colorless bichloride from ordinary water it may be stained with one of the aniline dyes, preferably fuchsin.

CHAPTER XIV.

THE OPERATING- AND SICK-ROOM.

Construction of the Operating-Room in a Hospital—At a Patient's Residence—Arrangement of a Sick-Room—Isolation of Patients with Infectious Diseases—Disinfection of Hospital Wards.

In pre-antiseptic times surgeons preferred to operate at a patient's residence, avoiding as far as possible the use of hospitals. This tendency was dependent upon a very general experience that the septicæmias prevalent and disastrous in hospitals occurred much less frequently in private practice. Pirogoff noted that the pyæmia and acute purulent œdema, which he vainly combated in the palatial hospitals of St. Petersburg, were never encountered in the miserable rooms of the poor peasants in Lower Russia. The significance of this fact was at that time not clear. The atmosphere of a hospital was held responsible for the infections which occurred. It was thought to have been contaminated with pathogenic germs. It is not surprising that the operating-rooms did formerly act as hot-beds of infection, considering how little attention was given to their cleanliness. The treatment of infectious wounds in a certain place must be conducive to the aggregation here of infectious organisms, if the strictest precautions are not exercised in the removal of pus and other products, and all articles maintained in a state of absolute purity.

In Chapter II. we stated that it is unnecessary to take any special measures in the disinfection of the air of an operating-room, if we simply avoid the clouding of dust. Contact-infec-

tion must be combated however with increased precaution, and in the designing of the operating-room and its furnishing, provision made for ready cleaning and disinfection.

It is better to have at least two rooms ; one for infectious, the other for non-infectious cases, and thus insure isolation. In some instances want of space, however, in others lack of means or scientific understanding, renders this impossible. If we are required to use the same room for laparotomies, resections, and for the opening of phlegmons, the work must be properly divided. Examinations and operations upon infectious cases should always be postponed until after the other patients have been cared for. In the operating-room it is of prime importance to have the walls, ceiling, floor, and all utensils permissible, of mechanical cleansing. There should be an abundant water supply and materials used which will tolerate washing with soap and hot soda lye and direct irrigation. Whatever tends to increase the difficulties of mechanical cleansing—ornamentations, grooves, niches, and furrows—should be avoided in the manufacture of furniture and utensils, and especially in all instruments used directly about the patient. The floor in the operating-room should be watertight and provided with a drain. The walls must permit of irrigation, at least to a height of six or seven feet. The floor may be formed of terrazzo (Hallenser Clinic), or pressed clay—Dutch tile (Royal Clinic, Berlin). Asphalt, on account of its permeability and softness, cement by reason of its friability, and oleated plaster-of-Paris (tested for a time by Dr. Rotter in St. Hedwig's Hospital, Berlin), in consequence of the rapidity with which it wears away, are not well adapted. Linoleum lasts fairly for a time in a room not used extensively. As a coating for the walls a variety of materials has been used. Enamel lac (Neuber's Clinic in Kiel) is recommended. Dutch tile, clay, and glass plate (Poncet's operating room in

Lyons), opaque (milk) glass (Schede's Eppendorfer Hospital), and marble (Schonborn's Clinic in Wurtzburg), are serviceable, although between the individual pieces grooves and furrows are liable to be present. A smooth coating for the walls recently recommended as superior, is polished white English cement (Marien Hospital in Hamburg and von Bramann's University Clinic in Halle).

On one side of the operating-room there should be a wash-stand containing at least two basins. To it hot and cold

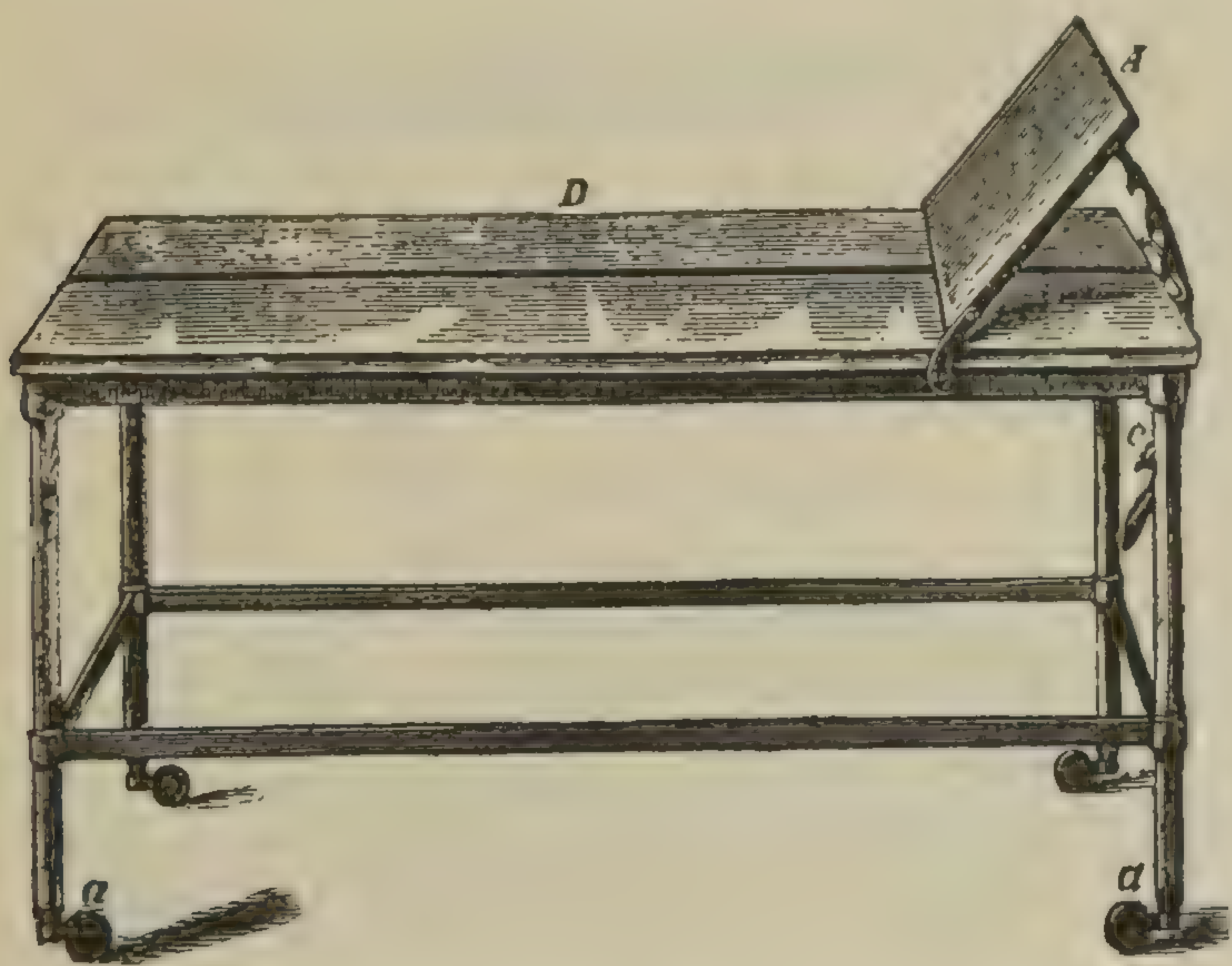

FIG. 37.

ROTTER OPERATING TABLE.

water should be supplied. The wash bowls which are emptied by revolving on an axis over a drain are difficult of being cleansed, and therefore are inferior to the fixed basins with outlet in the bottom. The simplest device is that seen in Neuber's private clinic, in which, set into the wall, there are wide and thick glass plates, upon which rest ordinary wash-basins. Into these the water flows from faucets. After use the water is emptied upon the floor and serves for irrigating the latter. The operating table and other tables and chairs used in the

clinic are made preferably of glass and iron or of wood and iron (*vide* Figs. 37 and 38), so that they may be washed with hot soda (soap lye), or sterilized in a large steam chamber. They must be as smooth as possible, and free from grooves, hinges, and ridges. To protect the patient against pressure the table is covered with a rubber cloth one and one half cm. thick, spread with linen, which is renewed frequently during the operation. Sterilized linen towels are laid about the patient. As stated in Chapter VII. the dressings should be placed in

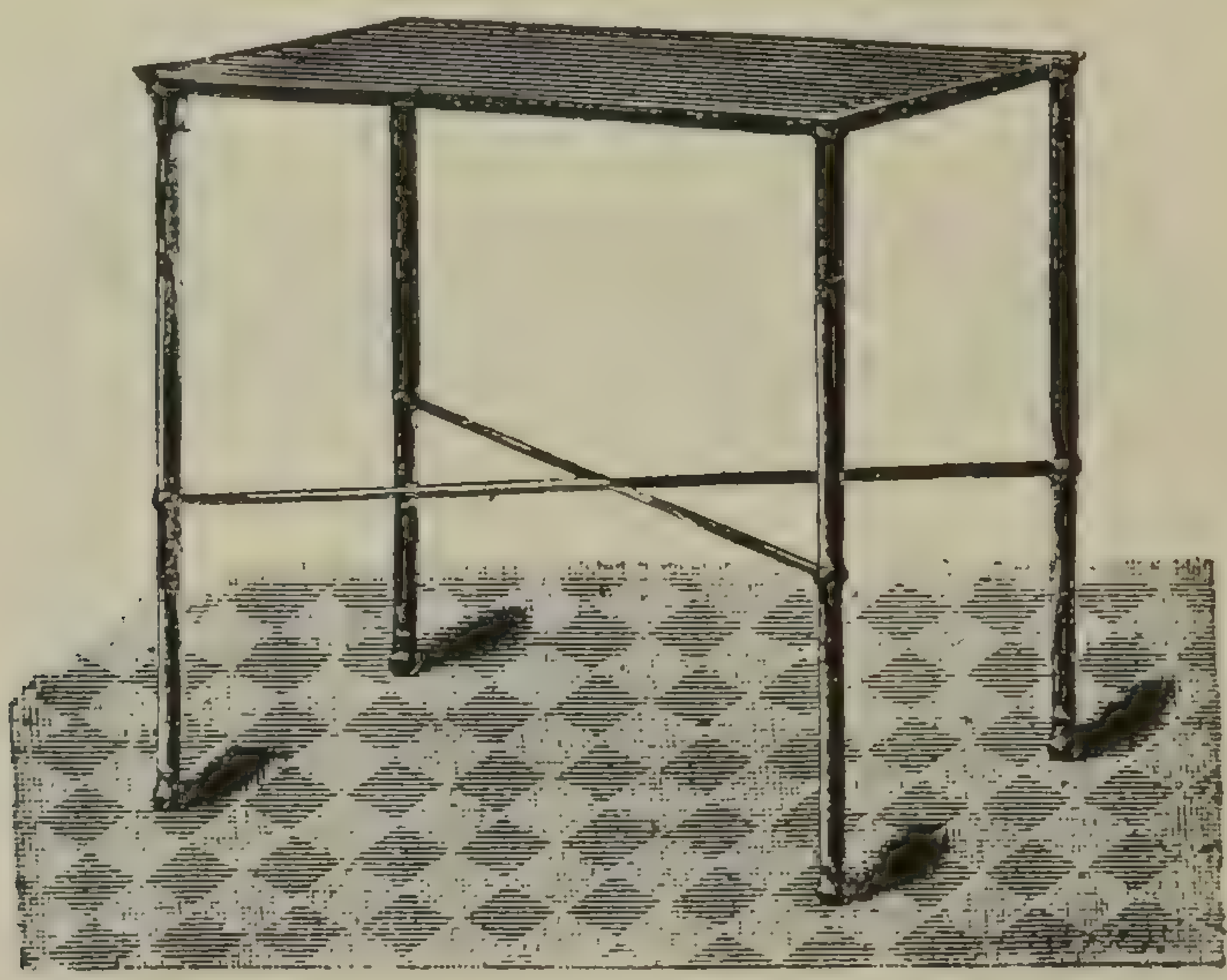

FIG. 38.

IRON TABLE WITH GLASS TOP.

sterilized boxes, and not in the expensive cases often used. The dressing sterilizer should be located in the operating-room and be under the scrutiny of the surgeon. In the immediate vicinity there should be situated an instrument sterilizer. The instruments are kept in a cupboard easily cleansed, upon glass plates, or may be placed in a recess in the arena or operating-room. The steaming, boiling, washing, and abundant use of water generally cause the atmosphere to become very moist, and while the main tendency of this is to prevent

the raising of dust, it has an unfavorable influence upon the instruments and tends to cause them to oxidize. Adjoining the operating-room there should be a small apartment in which splints, extension apparatus, etc., can be applied. Within the operating arena there should be a case containing antiseptic and sterile solutions, enamel, glass, or porcelain, receptacles for alcohol, and the necessary medicines, ointments, etc. Here there should be a device for heating substances when necessary. Pus basins and a pail are essential for removing dressing and refuse materials. These articles should not be thrown upon the floor, and when full the pail should be emptied. Leading from the operating-room into the basement or cellar there should be a slot closed at the top by a tight cover. Through this the patient's soiled linen, towels, aprons, bedclothes, mackintoshes, and operating gowns are thrown into a common receptacle placed underneath.

In operating at a patient's residence the conditions above detailed naturally can not be provided, but here we have in our favor the observation of the older surgeons, to which we have already referred, viz., that in private dwellings the germs of infection are not found as often as in hospitals. Under favorable conditions of cleanliness we may calculate upon their absence. In the selection of a room the light is usually determinative, otherwise the apartment least used is chosen. This, according to bacteriological investigation, contains fewest germs. Many operators order a room freed of its contents completely, the curtains being taken down, pictures removed, etc. To this there can be no objection, if it is done a sufficient length of time—six to eight hours—previous to the operation. Practised immediately preceding the operation the work may readily prove dangerous, as it causes the dust to become stirred up, and the air becomes filled with germs. After the removal of the furniture the room should

be closed for a number of hours in order that the dust and dirt may again settle. Immediately before the operation it is well to refrain from any disturbance of a room, and obviate the raising of dust and the dissemination of dirt. A free supply of sterilized towels should be provided. In case of emergency newly washed and ironed bed linen may be used for laying over the operating table, stands, and chairs.

The aseptic requirements of the sick-room consist, aside from favorable hygienic environments, is the provision for thorough cleanliness. The practice in vogue in many hospitals of preparing the beds for further use immediately after they have been vacated is to be condemned. The sick-room and its contents must permit readily of disinfection. In its construction requirements similar to those held as essential in the operating-room should be conformed with. Glass and iron are used as far as possible in the construction of tables, chairs, and beds, and floors and walls are coated with terrazzo or an impervious layer of paint. Tile and cement have proved superior to boards in many large hospitals. The objection of such floors becoming cold is obviated by a proper warming arrangement.

Good facilities for bathing and douching are among the most important adjuncts of the surgical department. In the preparation for an aseptic operation and in the after-treatment the bath plays an important rôle.

The subject of the change of dressing merits particular notice. Often it has to be done in the hospital ward or in the patient's room. The work, then, should not be undertaken immediately following the morning cleansing, as more bacteria are found in the air of the room at this time, owing to dust having been set in motion.

The aseptic cases should be cared for first; infectious ones later. Articles used in the dressing, the wash-basins and

instruments, are transported from bed to bed in a ward carriage. A mackintosh is placed under the patient in bed, and sterilized towels are laid about him. Here, however, perfect asepsis is rendered difficult. In large hospitals it is better to make provision for the dressing being done in the arena or a separate room designed for the purpose. The patient in bed is then laid upon a stretcher and brought to the place to which we have last referred. The greater convenience of this arrangement, the ability to resort to minor surgical acts, and the exclusion of other patients, are particular advantages.

Even more important than the selection of a place for operating is the isolation of infectious surgical cases. As we isolate patients with typhoid fever and pulmonary tuberculosis by placing them in different wards, so also should the erection of separate pavilions for transmissible surgical diseases be encouraged. The association of the various patients with one another, and the care of them by the same attendants, is a great source of danger. The septic cases should always be removed from those pursuing an aseptic course of repair.

In accordance with general hygienic laws, but more especially for aseptic reasons, a sick-room should not remain long in continued use. At specified intervals, at least once annually, a thorough disinfection should be instituted. The necessity of this is made obvious by the repeated occurrence of a certain form of infection in a ward or sick-room. The methods recommended for the disinfection of sick-rooms are so numerous that in a short treatise like this their detailed consideration would be impossible. The use of chemical agents, fumigation with sulphur, corrosive sublimate, bromine, and chlorine, and the spraying with carbolic acid, creolin, etc., in view of our present knowledge, cannot be regarded as of much value in antagonizing pathogenic germs commonly adherent to the furniture and walls of a room, in the form of dirt

or particles of pus. The means to be preferred for disinfection in this instance are those recommended elsewhere for securing asepsis. Systematic and mechanical cleansing of the room is placed in the foreground. Articles, which can be, are scrubbed with hot soda lye, painting is renewed, and the walls rubbed with bread (Esmarch) if they cannot be whitewashed or frescoed. The bedding, curtains, etc., when possible, are sterilized with steam.

The walls and ceilings of the new pavilion of the v. Bergmann University Clinic in Berlin are painted a light oil color, and the floor is formed of cement. The bedsteads and other articles of furniture are made of wood or iron so that they permit of being washed. The pavilion is disinfected in the following manner: The floor, walls, ceiling, bedsteads, and other articles of furniture, the windows, doors, etc., are scrubbed with a brush and hot soda lye, after which they are irrigated with water. Bed clothing and all washable articles, including the window curtains, are sterilized in steam. All unnecessary articles are destroyed. The pavilion is then vacated for six to eight days, and thoroughly ventilated by allowing the windows and doors to remain open day and night.

CHAPTER XV.

ASEPTIC OPERATION AND WOUND TREATMENT.

A Mammary Amputation after von Bergmann's Method—Arrangement for an Aseptic Operation—Preparation of the Patient, the Utensils, and the Medical Attendants—The Operation Proper—Aseptic Chloroform Mask—Care of the Wound—Importance of the Control of Hemorrhage and Drainage—The Wounds are not Irrigated with Antiseptic Solutions—Wound Suturing and Tamponing—The Temporary, Permanent, and Continued Tampon—The Dressing—Its Object—The Permanent Dressing—When the Dressing shall be Changed.

THE simple and more comprehensive method by which we can gain an impression of an aseptic operation and the after-treatment is to draw a typical picture of the manner in which von Bergmann executes a mammary amputation. We will assume that the patient awaits the operation at the clinic hour of two P.M. After her morning coffee at eight o'clock the patient receives nothing more to eat or drink, so that the stomach is empty and the possibility of vomiting during the administration of the anæsthetic is obviated. When that occurs it leads to unpleasant complications, and disturbs the conditions of asepsis. Just before the operation is begun a full, warm bath is given, in which special attention is paid to the thorough soaping of the entire thorax, the mamma and the arm on the side on which the operation is to be performed. The axillary space is shaved, and then the patient is placed in a bed spread with newly washed linen, after which she is transported to the operating-room. In the meantime the bandages and sponging material (gauze and pledgets) are asepticized in a

steam sterilizer, which occupies a place in the operating-room. The closed tin boxes with their fresh contents are placed upon a table covered with sterilized linen.

A box containing exclusively gauze pledgets in pieces 20 cm. square is now placed close by the operating table. The

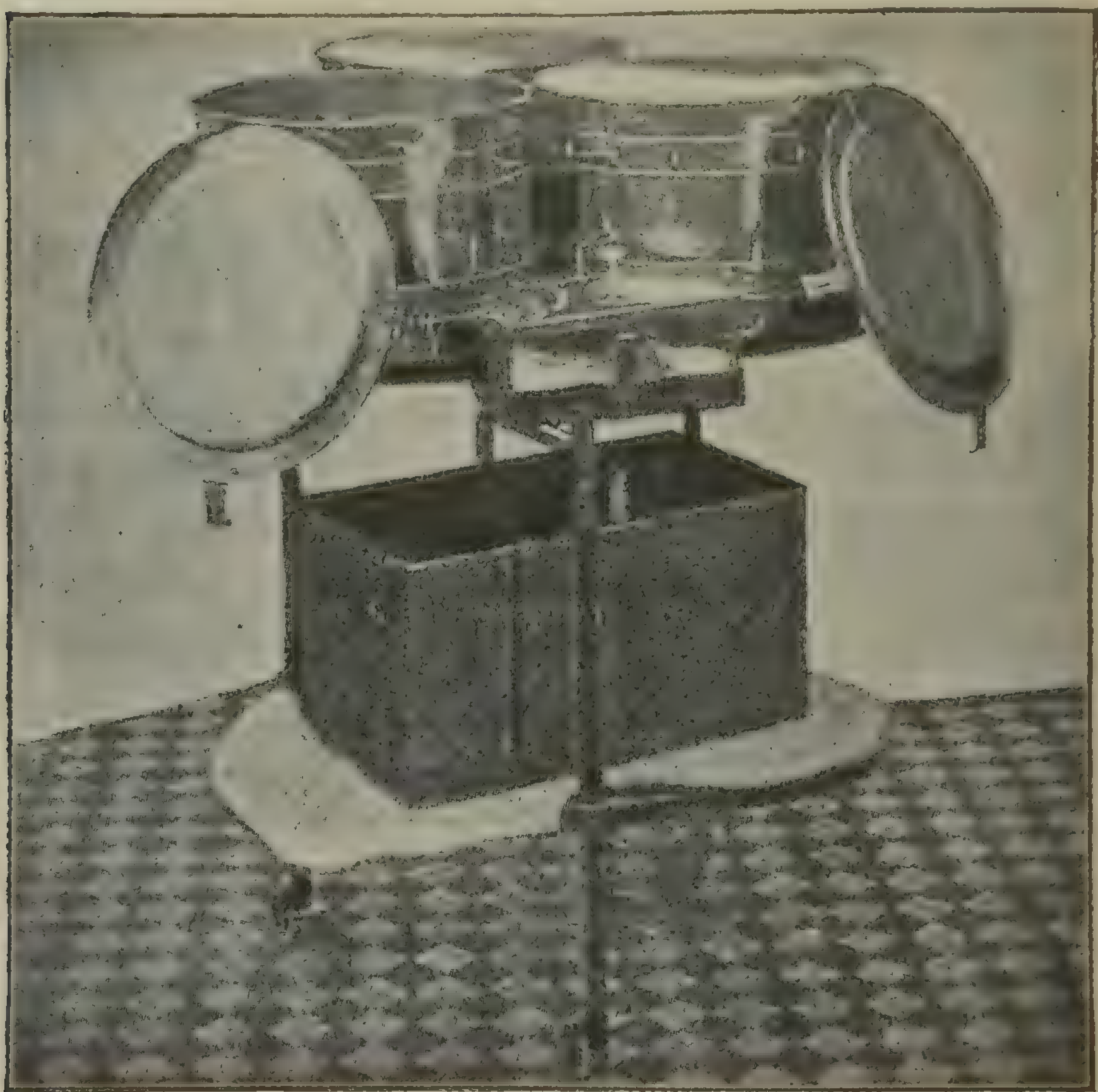

FIG. 39.

GAUZE, COTTON, AND BANDAGES STERILIZED IN SEPARATE BOXES; THE LATTER OPEN AND READY FOR USE REST UPON A TABLE COVERED WITH STERILIZED LINEN.

pieces are cut of the proper size before being put into the sterilizer in order that they may be removed conveniently. After the operation has begun and the absorbing pledgets are required, the receptacles are opened and the pieces handed to the operator or his assistant, by the nurse. Three receptacles, one

containing the loose gauze for dressing, one containing rolled absorbent cotton, and the third filled with bandages, are situated close by but are not brought forward and opened until needed after the operation for the dressing. Before the

FIG. 40.

ATTIRE OF THE PHYSICIAN AND ATTENDANTS IN THE VON BERGMANN CLINIC.

Male Attendant. *Clinic Nurse.* *Physician.*

patient is placed upon the operating table the instruments are selected, laid in a wire tray, and boiled in the soda-sterilzer.

During the operation the instruments rest in shallow trays filled with carbolized soda—carbolic acid and sal. soda one per cent. each.

Bottles containing catgut, silk, and drainage tubes are placed convenient to the field of operation. The operator, assistants, and nurses have prepared themselves for work. The surgeons wear long, white sterilized linen gowns ; the nurses and attendants are attired in washable linen. The female nurses wear aprons, the male attendants linen jackets in addition to aprons. Every individual engaged directly in the operation must have his forearm bare midway to the elbow. Every one must disinfect his hands with the utmost precaution, following the instructions given in Chapter V. Next in order the patient is placed upon the operating table and chloroformed. She is then covered with a large sterilized linen sheet, and under the latter her clothing is removed. The field of operation is now disinfected, the breast, arm, and neck being actively brushed with hot water and soap. Then with a dry towel taken directly from the sterilizer the skin is rubbed and finally washed with alcohol and corrosive sublimate. The patient after having been cleansed is wrapped anew in sterilized sheets, one of the latter extending from the lower boundary of the region of operation over the abdomen and extremities ; a second sheet covers the upper boundaries of the field of operation, including the neck and opposite side of the chest. The hair upon the scalp, the wig or braid, is enveloped in a sterilized bandage moistened with corrosive-sublimate solution. This insures its more firm adjustment and obviates a tendency toward its slipping off. One assistant administers chloroform, another attends to the pulse, a third or fourth assists the operator. One nurse hands the instruments, another attends to the gauze pledgets and bandaging material.

The operation having now begun, the bleeding vessels revealed by the individual incisions are immediately caught by a clamp or hæmostatic forceps. Capillary oozing is controlled by pressure with gauze pledget. As soon as the mamma is

removed and the axillary space is cleaned out the vessels to which the forceps are attached are ligated with catgut. The wound's surfaces are then separated by retractors and carefully scrutinized with reference to the presence of any other bleed-

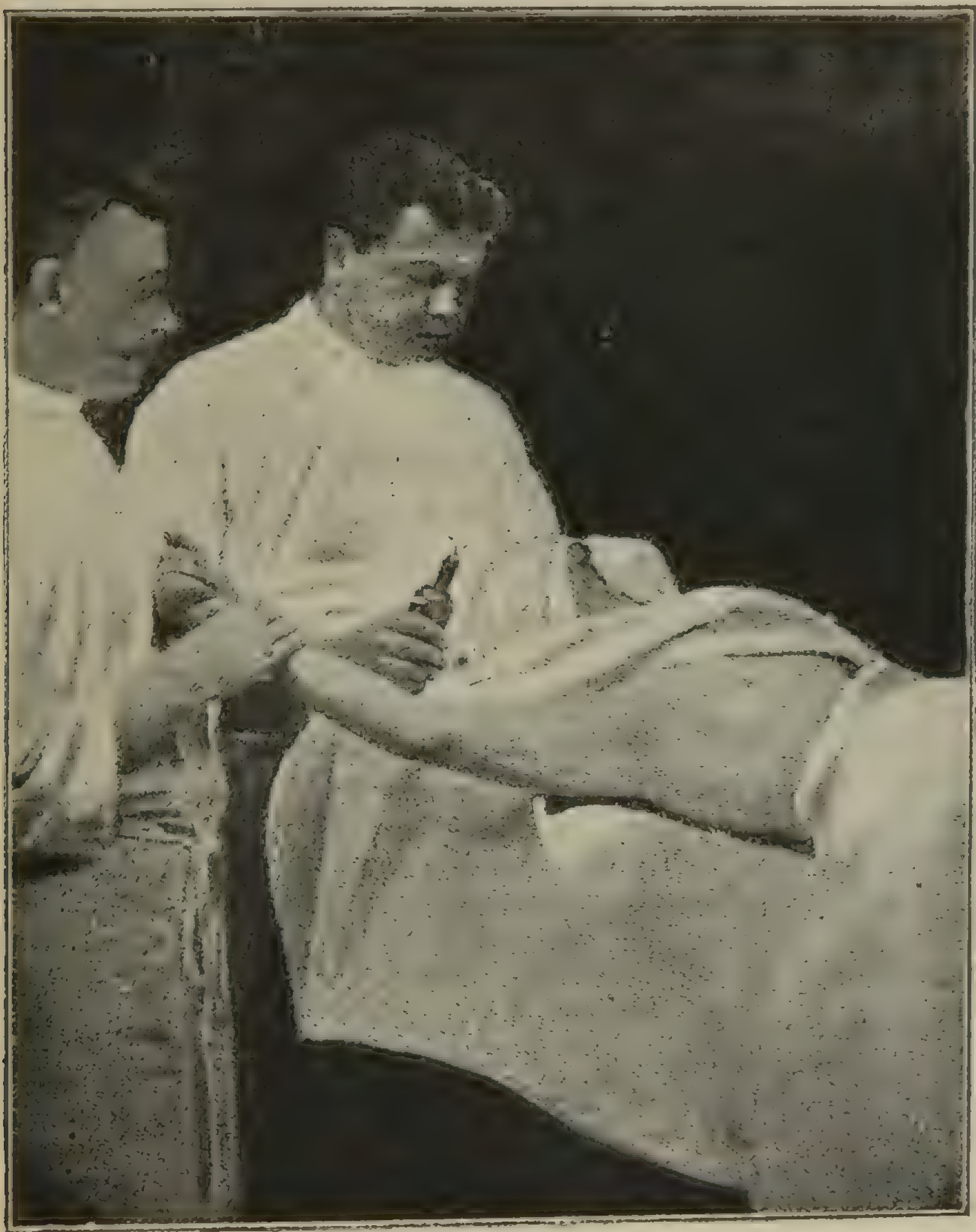

FIG. 41.

ing vessels. Every point, even the minutest, is picked up, isolated, and ligated.

Large wounds are packed temporarily with gauze and the flaps approximated. This opportunity (the closure of the

wound) is utilized for removing the blood from the skin in the vicinity. The latter is done by use of the pledgets and sublimate. The surface is then dried. If the sterilized sheets upon which the patient rested have become very much saturated with blood they are removed and clean ones substituted. The wound is re-inspected carefully with a view of determining whether from any point blood still oozes. After being abso-

FIG. 42.

lutely dried the skin is united over the wound by means of silk sutures, irrigation with antiseptic fluids at no time having been used.

Where pockets form and the skin is not adapted perfectly, conditions especially liable to be present under the latissimus muscles and on the anterior surface of the thorax, one or two drainage tubes, according to requirements, are introduced.

The whole surface is now dried, after which the dressing is applied. This must compress moderately and uniformly the wound's surfaces, especially in the axilla. Sterilized gauze pledgets are packed into the latter space, filling it out completely.

The skin originally baggy and pendant is thus made to approximate the walls of the freely dissected axilla. The dressing will conform to the ancient hollow pyramid in its shape. To this, as is known, the axilla may be likened. Ten to twenty layers of gauze are applied over the entire line of suture, and extend a sufficient distance beyond the latter to cover the anterior and lateral surfaces of the thorax on the side under consideration. By turns of the soft, deolated cotton made into a roll, together with muslin bandages, the gauze is held in place. The arm from the fingers to the outer border of the axillary space is enveloped in cotton and bandaged. The forearm is then placed at an angle of about 60 degrees with the arm and compresses the thorax about as firmly as is done when making thermomeric observation in the axilla. The space intervening between the arm and axillary cavity is filled with a suitable quantity of loose gauze and cotton. The neck is encircled by strips of cotton which are brought down to the sides of the thorax. Thus the successive layers of the dressing form a continuous covering of the thorax, arm, and neck, the closure being everywhere complete and no external communication permitted.

This dressing remains for eight days. If the desired result is obtained, there is union along the entire suture line, and a portion of the silk thread may be withdrawn. The drainage tubes are removed, and a light, simply retentative gauze dressing is applied. The latter is allowed to remain until recovery, or when the patient is discharged from the hospital. This, as determined by the extent of the operation and the condition of

the subject, occurs five to eight days later. The channels in which the drainage tubes of proper size were laid are studded with healthy red granulations ; the walls are elastic and collapse readily by reason of their inherent tendency, then heal. An operation may be divided into five stages.

1. The preparatory.
2. The operation proper.
3. The care of the wound.
4. The dressing.
5. The change of the latter until recovery.

The preparation comprises three acts : (*a*) The preparation of the patient, (*b*) of the articles required in the operation, viz., the dressings, etc., and (*c*) the preparation by the surgeon and attendants of themselves.

The arrangements in regard to the patient are not always the same as in case of the mammary amputation cited. In some instances they must precede the operation by a much longer time than in others. A region of the body with neglected ulcerations or eczema must be improved by proper dressings, the eczema healed, etc., in order to facilitate the securing of aseptic conditions. Operations upon the stomach and intestinal tract should be preceded by purgation and levage, precautions which in amputations and resections of the rectum are of the highest importance.

But in many instances, an extensive course of preparation is absolutely impossible. Immediate execution of the operation or dressing may be demanded. A complicated fracture or herniotomy, for instance, permits no delay. In an acute injury the bath must also be dispensed with, and for the disinfection of the surface a thorough soaping and rubbing with towels, alcohol, and ether, as well as with sublimate solution, substituted. Of extreme importance is the placing of sterilized towels about the patient and the limitation by them of the field of operation.

This permits the unconscious contact of the hands of the operator and of the various utensils with the non-disinfected regions about the field of operation. It permits the laying down of instruments, and provides a place upon which the surgeon can rest his hands and arms, makes spontaneous movements of the patient harmless, and is, generally speaking, a precaution of the first order. For limiting the field of operation, spreads of oiled silk or mackintosh were formerly employed, although these cannot be asepticized readily, owing to the inapplicability of heat, and the only means remaining for their disinfection is by soaping and washing with antiseptic solutions. Clean linen towels sterilized in steam are decidedly superior. It would be of material advantage to the surgeon and greatly add to the feeling of certainty if all articles used could be disinfected immediately before operating, and the work could be conducted under his personal supervision. But this is possible only with reference to such articles as the metal instruments, which are sterilized in boiling soda. The latter is quickly provided, and is rapid in its action. It is just the metal instruments that it is desirable to disinfect immediately before the operation, as usually it is only possible to collect those which are needed at this time. For the preparation of the articles which we sterilize in steam—the bandages, gauze and towels—there would, as a rule, not be sufficient time just before operating, as the generation of the steam and the permeation of the articles to insure disinfection occupy the greater part of an hour. These articles, and others which require more extended treatment, as the catgut and sponges, must be prepared some time in advance. The more recently the materials sterilized in steam are prepared, the better it is naturally, although they may be disinfected several days in advance if they are protected from re-infection. To insure the latter, use of the sterilizible dressing receivers is of great importance.

Opinions as to how the surgeon and attendants shall prepare for an operation or for surgical work generally, are at the present time much varied. Many surgeons attach no importance to scrupulous cleanliness, while others contend that always before operation it is necessary to wash in carbolic acid or bathe in corrosive sublimate. The former of these is blamable, the latter superfluous. It is well always for the entire surgical staff to exercise personal cleanliness, and this should be facilitated by good bathing arrangements. Next in importance is the clothing because, after the hands this harbors the greater number of bacteria. In large surgical clinics the staff and attendants must to a certain extent be uniformed and provided freely with aprons and gowns which can be washed. The surgeon and his assistants must positively never wear their every-day clothing, but instead have an attire especially for operating. Large aprons of rubber or oiled silk have been much used, although they are not to be recommended. As stated in considering the articles of clothing upon which the patient rests such materials are with difficulty maintained aseptic. Linen aprons and large linen gowns sterilizible for each usage are much to be preferred.

We will now direct attention concisely to the subject of anæsthesia in operating. Certain rules must govern the latter, referable to asepsis, which may be neglected in case of an accidental asphyxia owing to the danger in delay. The patient's head should be turned away from the operation so that in vomiting, expectorating, or coughing the wound is not contaminated. For instance, if the right breast is to be amputated the head should be turned to the left. The instruments used in administering anæsthetics, especially the mask, should receive attention, particularly in operations about the face and oral region. Erysipelas, diphtheria, and other diseases may readily be communicated by an infected mask or mouth gag ;

besides we have the septic danger ensuing from the apparently harmless saliva when it encounters wounds. The mouth gag may be sterilized with the other instruments in soda, and the author has devised a mask the framework of which can also be placed in the boiling alkali, and for each anæsthesia be covered with new sterile gauze.

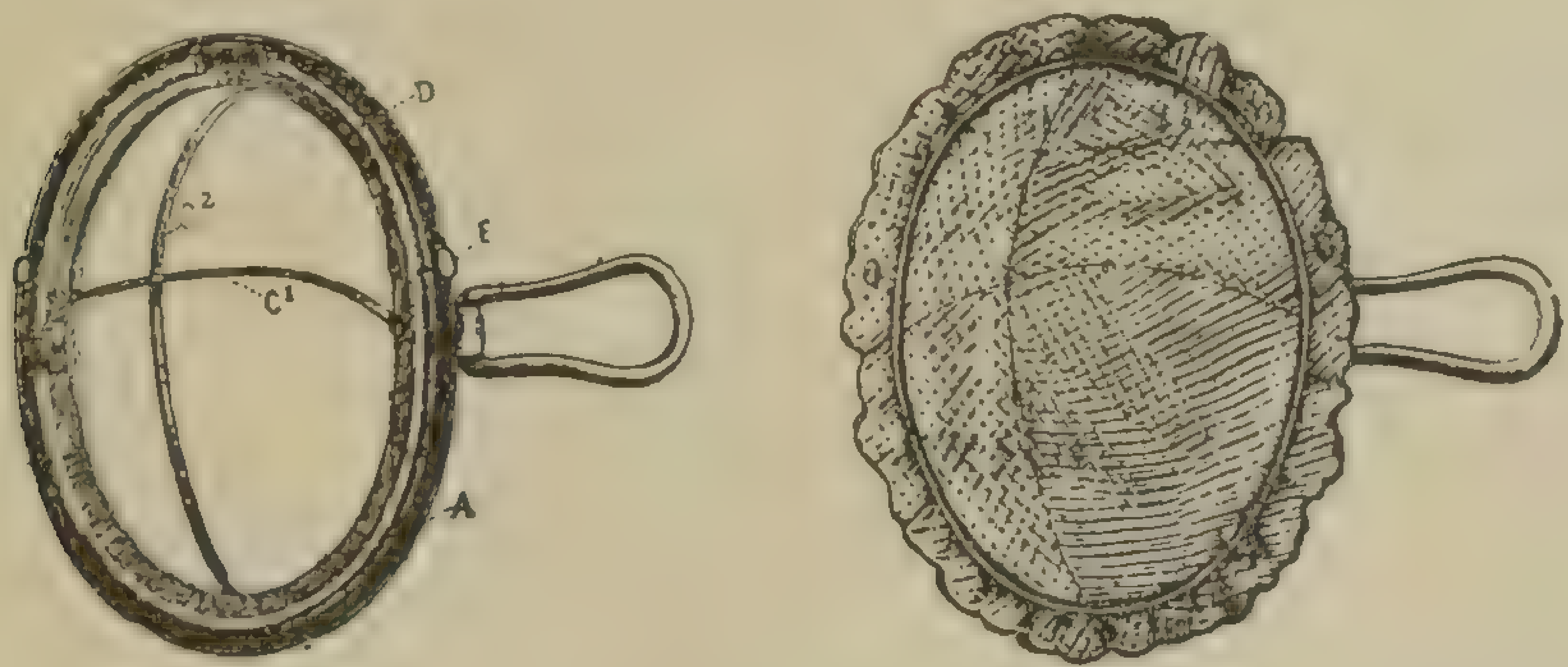

FIG. 43.

ASEPTIC CHLOROFORM MASK (SCHIMMELBUSCH).

The masks in use at the present time for chloroforming, aside from the complicated apparatuses for administering anæsthetics generally, are with difficulty cleansed thoroughly. So also are the Esmarch and Skinner masks much employed, and consisting of a simple wire framework with attached cover, not easily kept clean. The cover must fit properly and the making of a new one for each anæsthesia would be too expensive. Frequent disinfection by washing causes the covers to shrink, the meshes becoming narrowed; thus the material gradually loses its permeability to air. In administering chloroform this is very serious, because the necessary dilution of the vapor by the atmosphere is precluded and there is greater danger of asphyxia. In the mask devised by the author the cover may readily be removed each time it is used. The instrument consists of a framework over which a piece of any material of the proper size may be extended. Preferably a number of layers of absorbent gauze are taken. The mask is made of a ring grooved deeply and shaped to conform to the contour of the face. On one side of the ring the handle is attached, and this may be turned upon the ring. On each side directly opposite, the bows C^1 and C^2 are fastened. The latter may be placed erect or laid flat. The wire spring D, which may be elevated by means of side pieces E, E, rests in the groove. In using the cone the bows are placed erect, when they snap into position across one another;

the spring is then elevated and the several layers of gauze placed over the mask. The wire is now brought down upon the gauze, pressing the latter firmly into the groove of the ring. The surplus material is cut away with the scissors around the margin of the frame, the precaution being taken not to cut too closely.*

The asepsis present at the beginning must be maintained throughout the operation. Quiet working and the avoidance of haste are conducive to this end. Very important is the training of the attendants. The latter must be sufficiently competent and reliable to permit of the surgeon's attention being diverted without a disturbance of the aseptic technique. If it becomes necessary to discontinue the operation for a time the wound is covered with gauze and closed. Quite as requisite to recovery as the exclusion of bacteria is the proper care of the wound after the operation. The latter must favor union and be antagonistic to germs.

Not infrequently we have to operate upon infected tissues or a region of the body where the egress of micro-organisms is unavoidable. Such localities are the intestines or mouth, for instance. But even where complete disinfection is possible, as in amputations of the breast, it is not well to regard asepsis as infallible. Every one who is familiar with bacteriological work knows how very difficult it is to avoid contamination of our culture media in the laboratory, and how such contaminations do occur even under the strictest precautions. With much less certainty can we calculate upon the *absolute* exclusion of micro-organisms, in an operation in which varied and uncontrollable factors are present.

Major operations may be performed successfully under strict asepsis and control of hemorrhage, then closure of the wound, without attention to the delayed accumulation of blood and se-

* This mask is manufactured by Jetter & Scherer, Berlin, and may be obtained from them or Jeffrey & Gotshall, Buffalo, N. Y., and other instrument dealers.

cretions, for we have in large subcutaneous, injuries, as fractures, evidence that repair does take place in this way. There is, however, in operation wounds absence of such certainty of a favorable termination as is present in injuries without any external communication. While perfect recovery in simple fractures appears natural, we cannot claim that corresponding conditions exist where the integument is severed and an avenue for the entrance of micro-organisms is produced. Even under the most rigid asepsis a similar form of termination must be rare. There are three conditions which experience has proved to be favorable to infection.

1. The presence of blood in the wound cavity.

2. The accumulation of secretions.

3. The presence of detached or poorly nourished tissue particles. To exclude these is to antagonize directly the occurrence of infection and prevent it.

In no particular does the ancient and modern science present greater contrast than as regards the estimation of the effect of blood and secretions in wounds. The older surgeons believed both to be "healing." The plastic material was thought to serve for the regeneration of the tissues and to form the cicatrix. To us it acts at most as an irritant, often retarding the healing process and favoring infection. We no longer believe that in wound secretion connective-tissue cells develop spontaneously, and that the blood "organizes" and becomes new growth. We know at the present time that repair ensues only through regeneration of pre-existing cells, and that everything which interferes with the aglutination of the tissues retards recovery. Blood, secretions, and separated tissue particles we regard as useless organic material, which, it is true, remaining simple, is absorbed, though slowly, but which, when it becomes the nidus of pathogenic organisms and decomposes, gives rise to the most serious of wound complica-

13

tions. For this reason it is extremely important to control the hemorrhage with the utmost care, institute drainage, and avoid laceration of the tissues in operating. A decade ago, von Bergmann announced that the surgeon who does not insure cessation of the last particle of bloody oozing in operating must have the results of his aseptic efforts surrounded by uncertainty. The experience of subsequent years has confirmed his views. This rule regarding the control of hemorrhage is observed to-day in the Royal Surgical Clinic, Berlin, as most essential to union. In mammary amputations and solutions of continuity produced by trauma, even in minor operations, the wound is repeatedly inspected to make sure that the smallest bleeding point has been ligated. The surface must be perfectly dry. Where there are large cavities a drainage tube is always introduced. This form of drainage must be adapted to the individual circumstances, as a counter-opening is made for the same purpose in a fold or interdigitation of the skin or mucous membrane.

The latter is only to be omitted where the wound surfaces throughout their entire extent can be approximated either by sutures, pressure of the bandage, or natural tension of the tissues and accumulation of the secretions thus prevented. In doubtful cases it should be remembered how little the drainage tube interferes with union, and how much risk we run, on the other hand, by omitting it in lax, sinused, and irregular wounds. In the one case we have to deal with the danger of infection, and in the other with delay in union by only a few days. Where accumulation of bloody transudation occurs under the rapidly agglutinated edges of a wound, there will inevitably be observed a rise of temperature, and, even though this accumulation be evacuated, healing is retarded. In order to have the surfaces even and avoid laceration of the tissues in operating, the original incision through the skin should be

made *freely.* This is an important general rule, as only in widely-gaping, open wounds is exact control of hemorrhage possible. The conservatism to be observed in individual cases, just how bleeding is to be controlled and wounds drained, the surgeon can only learn by experience, and does not come within the scope of this treatise. The closure of the wound has been regarded as most important from an antiseptic standpoint, and this with propriety, as the closed wound is safer against infection than one which is not. As the healing progresses from day to day, the danger of infection gradually decreases. This closure, however, can only act favorably when there are no foreign substances intervening. Nothing is more disastrous than the suturing of a wound when pathogenic organisms are imbedded in its depth in blood and transudation. Here the closure is antagonistic to repair and conduces to infection. Where the entrance of infectious germs cannot be avoided and perfect control of hemorrhage is impossible, or where previously infected tissues have been the seat of operation, the wound cannot be closed, and must be covered simply with gauze or packed—tamponed. Here it is difficult to inaugurate fixed rules applicable in all cases. Only in a general way will the fundamental principles of tamponing be alluded to.

In the von Bergmann Clinic three methods of tamponing are employed :

1. The temporary tampon.
2. The permanent tampon.
3. The continued tampon.

As a rule the only article used for tamponing is iodoform gauze. In employment of the temporary tampon the wound is packed throughout its entire extent with this material, which is allowed to remain for forty-eight hours. It is then removed, and if the wound is in a proper condition it is treated as recent,

and the edges approximated and sutured. As a rule, a wound which has been tamponed for two days with iodoform gauze, if it were not previously infected, appears fresh and unirritated, as the dry wound does immediately after operation. Healing also progresses in a similar manner. The actual purpose of the temporary tampon is to check the delayed parenchymatous oozing, which occurs usually where large capillary areas have been opened up, as in case of resections. Here the gauze pressing upon the bone prevents the escape of blood until the vessels become closed by thrombosis. It is also of value where the surgeon is in doubt as to whether or not the wound, after an operation, is aseptic.

The permanent iodoform gauze tampon, which is often allowed to remain eight, ten, or even fourteen days, suppresses hemorrhage not controlled by ligation, or which would not have subsided under a tampon allowed to remain for two or three days. These are the hemorrhages which occur from the large venous sinuses of the brain. The iodoform gauze tampon should here be placed upon the bleeding point, and allowed to remain for eight days, or until there has been firm closure of the sinus by union of its edges. The permanent tampon has the effect furthermore of affording protection where infectious material would encounter the wound continuously or intermittently. Thus it is indispensable after resections of the upper jaw, removal of the tongue, rectum-amputations, etc. The iodoform gauze tampon, packed into the cavity which remains, in these cases becomes firmly imbedded without requiring particular fixation, and remains often for ten days without permitting decomposition of the absorbed secretions.

The continued tampon is indicated where infected wounds must be maintained open by reason of long persistence of the infectious conditions, as often occurs in the treatment of phleg-

mons, where necrotic tissue shreds continue to be extruded. When the secretion is very active, and the pus is thick and tenacious, also where the wound has a relatively great depth, this method of treatment does not suffice, and after the hemorrhage has been controlled by the temporary tampon it is recommended to introduce the rubber drainage tube early, in order that the discharge may be better carried off.

One of the most essential features in which the method of treatment practised at the present time in the von Bergmann Clinic differs from that frequently employed elsewhere, is in the non-use of antiseptic irrigation of wounds during and after operations, and at time of the change of dressing.

To Landerer belongs the credit of first having directed attention to the superior advantage of the dry treatment of wounds. A trial of this method was at once begun in a few cases in the von Bergmann Clinic, and in a short time it became universal by reason of its manifest superiority. For some time previously, however, wounds had not here been irrigated in the usual manner, injecting into them through a rubber hose antiseptic solutions under high pressure from an elevated reservoir. Instead, the fluid was simply poured over the wound gently from a small hand irrigator. The forcible irrigation of suppurating wounds is dangerous, as it not simply washes away the pus and infectious secretions, but tends to force the latter into the interstices of the connective tissue, and thus disseminates rather than limits the infection.

When we review the advent of antiseptic wound irrigation, we must conclude that it never had a really reliable basis, either experimental or that emanating from surgical experience, but instead was founded upon hypotheses and assumption. As surgeons believed in the use of the spray for a time, so also was the irrigation of wounds regarded as essential. The general belief that a wound may be disinfected by means of antisep-

tic irrigation with the indications laid down for its application, was, like many other things, the outcome of custom. This idea was transmitted from one clinician to another, thus finding a fixed place in surgery without due authenticity and reliability. Consideration of the degree of tolerance possessed by wounds, on the one hand, and of the disinfecting power of antiseptic solutions on the other, led of necessity very early to skepticism regarding the value of irrigation, *i. e.*, as to whether or not it really could accomplish all that was claimed for it, and all that it should. Nowhere are the conditions for the working of germicidal agents so unfavorable as in the above instance. The essentials for success of the chemical disinfectant, the necessity for permeation of the substance acted upon, the avoidance of antagonizing influences, and a sufficient time for the action, are all wanting here. In recently infected, and particularly in old wounds, the elements of danger, cocci and bacilli, are imbedded in the blood clots, tissue particles, and dried secretions or crusts, and perhaps also in the interstitial connective tissue, and antiseptics, such as corrosive sublimate and carbolic acid are incapable, diluted, of permeating these substances to encounter the organisms.

The wounds are not thus disinfected and positive damage may be done by the poisonous and irritating chemicals. The sensitive tissue cells are destroyed long before the much more resisting bacilli and micrococci. Irritation and interference with the process of repair are ever obvious consequences of the antiseptic wound irrigation. One concession for this method of treatment is the removal of blood and purulent secretions. This may be accomplished, however, better by means of some non-irritating fluid,—a sterilized physiological (3/4 %) salt solution, or weak boracic acid solution ; or the blood and discharges may be absorbed with hydrophile gauze or some similar material. The latter mode of procedure has

been in use in the von Bergmann Clinic in all operations under infectious as well as aseptic conditions, and is exercised in the changes of dressing. Only in cases of very profuse discharge is one of the foregoing indifferent solutions employed.

Professional experience with the agents which restrict the development or modify the damaging influence of bacteria has been rather confusing and contradictory. A wound which is covered with green pus cannot be freed from the development of the bacillus pyocyaneus even by long-continued irrigation with sublimate solution. We possess in iodoform a better agent for restricting the proliferation of bacteria and rendering them harmless, at least in simple suppurating wounds. As iodoform counteracts the decomposition of absorbed discharges in dressings, so also does it exert an antiseptic influence upon the surface of wounds, and does not damage the tissues or cause irritation with increased secretion. Just how iodoform acts antiseptically is not as yet thoroughly understood, but as to its having this action there is no question. According to the investigations of Behring and du Ruyter, its effect is principally upon the ptomaine products of the bacteria. In case of actively suppurating and offensive wounds, instead of applying iodoform gauze it is often better to use gauze saturated with a one per cent. solution of aluminium acetate. There is no antiseptic which counteracts blue pus formation better than the latter solution.

We have already described (Chapter VIII.) how an antiseptic dressing is to be applied so as to protect the wound from infection until the completion of repair. It was stated that the dressing must form a complete covering of the wound, be composed of aseptic material, absorb the secretions, and prevent their decomposition. Indications not less important than the antiseptic dressing for facilitating union are proper adjustment and immobilization of the injured part and mod-

erate wound compression. The compression of the wound has the important effect of preventing the accumulation of blood and secretions, and of thus perfecting what careful control of hemorrhage and drainage may have failed to accomplish.

The original Lister dressing was changed almost daily or even twice daily. This was necessary, because it was composed of moist layers of carbolized gauze and a waterproof impermeable covering which acted simply as a Priessnitz application, "compresses echauffantes," as expressed by the French. In the absorbed secretions under the moist warm covering, notwithstanding the saturation with carbolic acid, bacteria soon develop. The secretion is also more profuse under this dressing, because warmth and the carbolic acid irritate the wound very decidedly, even though the latter has been covered with protective silk or disinfected guttapercha. The dressing rapidly becomes filled with secretions, taking up, as it does, more than the dry gauze, and it cannot dispose of the fluid absorbed, by evaporation. The superiority of the absorbing dressings consists in our being able to allow them to remain for long intervals, it being unnecessary to change them until the completion of repair, unless the discharge has been excessive. It is objectionable to have to change the dressing, as every such change exposes the wound to renewed danger of infection, and disturbs the position of rest and the compression. Of this we may readily convince ourselves in any case of progressive suppuration and in localized joint inflammation by the very decided rise of temperature which often follows. The aseptic absorbing and well adapted dressing must not be removed during the whole course of recovery unless there are urgent indications present. These latter comprise :

1. Inability of the dressing longer to absorb the secretions.
2. Particular soiling of the dressing.

3. Necessity for removal of the drainage tubes.
4. Evidence of infection.

Secretions of fresh wounds are taken up very well by dressings composed of gauze and moss. When the secretions penetrate to the upper surface of the dressings it suffices for preserving the aseptic character of the latter to apply additional layers of gauze, or simply provide for the contact of the air with the saturated areas. The object of the latter is to cause them to become dried. When the entire dressing is saturated with discharge the upper layer should be removed, the deeper remaining undisturbed. Frequent changes are necessary in ichorous and offensive wounds, because even the gauze absorbs with difficulty the tenacious pus, and the latter stagnates under the dressing. Here a change, at intervals of twenty-four, forty-eight, or seventy-two hours, is required. Especial precaution must be taken against outward soiling of the dressing in regions of the rectum and genitalia. When in the latter situation the gauze and bandage become saturated with urine or soiled with fæces, this portion must be removed.

In the von Bergmann Clinic the drainage tubes are removed on the sixth or eighth day. As a rule, union is then complete, so that the greater number of sutures can be dispensed with. The drainage tubes are removed *in toto* at one time, and not gradually shortened. The small fistulous tracts remaining, close in the course of a few days. The presence of the tube after the end of a week is unnecessary, it having at this time no further function to perform, and it prevents the complete closure of the wound. It must not be supposed, however, that a tube left for a longer time would be a source of danger. Through error this once occurred in the von Bergmann Clinic, a drainage tube being allowed to remain for five weeks, and, notwithstanding, no particular disturbance was occasioned. After its removal the wound healed rapidly throughout its en-

tire extent. The extraction of the drainage tubes with the change of dressing is the simpler and better method. Allowing them to protrude through the gauze, or attaching threads to them to facilitate their removal in course of a few days, is not to be recommended, as the position and aseptic character of the dressing are thus jeopardized. A direct external communication is created. The frequent changes of dressing in the former Lister method was regarded as necessary in order to enable the surgeon to determine early whether infection had anywhere taken place. Necessity for this seems very apparent. With the occurrence of infection most energetic measures are to be adopted. All, or the greater number of the sutures should be removed, the wound laid open, packed with iodoform gauze, and drained. In the permanent dressing of to-day the direct "control" of the wound is excluded, and so much the more thoroughly must the surgeon study the symptoms which indicate to him, without such inspection, the presence of infection. It is very essential to understand the normal process of recovery. In case of the mammary amputation referred to, sensitive patients will complain of some pain on the day of the operation. On the following day, if the course is aseptic, this is substituted by simply a feeling of discomfort, due to the dressing. As the effect of the chloroform passes off, vomiting and headache subside, and the appetite and normal sleep return, so that in the course of thirty-six to forty-eight hours a quite natural condition is resumed. The character of recovery under the Listerian dressing led surgeons to suppose that where there is no reaction in wounds the patient is always free from fever. This is incorrect. Every experienced clinician will endorse the following statement of Volkmann; "It will very nearly be a true representation of the facts to assume that of one thousand cases of severe injury, properly treated, with all the aseptic precautions, only one

third are free from rise of temperature, another third have a moderate elevation, and the remaining number very decided pyrexia."

The so-called aseptic fever often reaches 39° and 40° C. like the septic. Typical illustrations of aseptic fever are afforded by nearly every large fracture. Von Volkmann studied in his clinic fourteen successive cases of fracture of the femur. Of these just three were entirely free from fever. The greater number showed 39° and 40° C. for several days, and in two cases the temperature was at this point for ten days, in one for eleven, and in one for sixteen days. This form of fever begins immediately after the operation; often when the patient has been operated upon in the morning, on the evening of the same day there will be a rise to 39°. The temperature may continue to increase, and attain a considerable height, then gradually decline. Almost never is that fever aseptic, which begins on the second or third day after the operation; here we have to do with infection. Usually in two or three days in uninterrupted repair, the temperature has returned to the normal, although it may remain high for a longer time, finally declining gradually.

The so-called aseptic fever does not belong properly to the aseptic course of repair. Like the septic, it is an absorption fever, being dependent upon the taking up of the ferment which the disintegrated tissue produces in the wound. These tissue shreds, and more especially the fluid or coagulated blood—the fibrin ferment (von Bergmann and Angerer)—cause the whole phenomena. This explains why the fever begins immediately after the operation, and herein lies the differentiation of this from the septic fever. The cause of the aseptic rise of temperature, the fibrin ferment, is produced with the formation of the blood clot and the disintegration of tissue. The ptomaines and toxines which are the cause of the septic

fever by their absorption, develop gradually with the proliferation of the bacteria. One germ or a number of germs produce no effect. Suppuration and fever—the consequences of the bacterial toxines—are manifested only when these products are manufactured in large quantities in the wound. There is always a period of incubation in infection therefore ; prior to the second day noticeable symptoms are almost never to be expected. Thus the first twenty-four hours following the operation affords little aid in the prognosis, and not until the second or third day are we presented with definite information.

Later than this the occurrence of infection is not to be expected. If on the second day there is no constitutional or local disturbance, it is evident that during the operation no infection occurred, and we can reasonably calculate on a favorable termination. Only rarely does this form of complication develop subsequently under the permanent dressing, and according to the weight of experience we have here rather to deal with a secondary inception of bacteria. The symptoms of beginning wound infection are local and constitutional—fever. The objective evidences of inflammation in the wound, the redness and swelling, are concealed from our view by the dressing, which, when possible, we allow to remain undisturbed. The pain of which the patient complains however, is often very distinctive. It is almost always present to a greater or less extent in inflamed wounds, and may be very severe. This symptom is more valuable when it was not present on the day of operation or on the first day afterward. Even though the wound cannot be inspected, usually its surroundings can, and the latter afford us valuable information. Nothing in this connection is more important than the condition of the lymphatics, and the first thing to be observed when sepsis is suspected is the character of the lymph glands in the vicinity, with a view to determining whether or not they are swollen.

The constitutional disturbance and fever in septic infection do not conform to any fixed rule. Infection is dependent upon a number of varied organisms, which form dissimilar toxines and affect the body differently. The height of the fever, which is non-septic, corresponds with the quantity of blood poured out in the wound, and with the extent of the destruction of tissue, while in the dangerous forms of sepsis the local disturbance may almost escape notice, everything being dependent upon the quality of the bacteria. The severest cases can also run a course unattended by particular elevation of temperature, and there only remains the abnormally hard or readily compressible character of the pulse, or the general condition of the patient, to indicate to the clinician the gravity of the prognosis.

Usually a patient affected with sepsis is depressed, or at least feels that he is ill. This sensation, however, may be absent in severe cases, and it is important to know that there may be an abnormal feeling of well-being, and yet the individual die in the course of a few hours, greatly to the astonishment of the bystanders.

CHAPTER XVI.

ASEPTIC EMERGENCY DRESSINGS AND THE CARE OF THE WOUNDED IMPROVISION.

The Examination of Fresh Wounds with Fingers and Probe is Unpardonable—So also is the Irrigation with Water—Control of Hemorrhage—The Dressing—Occlusive Bandage Applied to Small Wounds—Gunshot Injuries and Complicated Fractures—Injuries Involving Large Wounds—Improvisation.

One of the most persistent of former evils is the examination of fresh wounds with fingers and probes. In no particular does the ancient and modern treatment present greater contrast. The wound proper has been thought to be the chief source of danger. The exact determination of its extent, depth, and width, and the exploration for bone splinters, appeared the essentials of rational treatment. To-day we regard the liability to infection as the chief danger, and all efforts are directed towards the exclusion of the pathogenic organisms. The character of a repair seen formerly in extensive subcutaneous injuries is witnessed daily now by surgeons under the aseptic dressing. The most extensive fractures and wounds of the soft parts heal promptly in spite of splintering and contusion, if there have been no infectious organisms introduced. The exploration of fresh wounds with fingers and probes must therefore be avoided.

The common practice of irrigating wounds with water we must also condemn as one of the inconsistencies of former treatment. This has been regarded by many surgeons as the

first indication. Water obtained from any source, whether a pond or a contaminated reservoir, has been poured over the injured area, carrying with it thousands of micro-organisms, with the belief that the wound is being cleansed. Nature supplies her own irrigation, and one most effectual, in the welling of pure aseptic blood out of the bottom of the wound, and nothing affords a better provisional protection than the freshly formed blood-clot. Only in case of extraordinary contamination with mucus or dirt is irrigation permissible, and then only water which is aseptic should be used (see Chapter XIII.).

Third in importance in aseptic emergency dressings is the proper control of primary hemorrhage. Here the use of styptics is to be avoided, and also the application to the wound of astringents and cauterizing substances, as acetic acid, tincture chlorid of iron, etc.

These agents damage the tissues seriously, contaminate the surface of the wound, retard the healing process, and interfere with the effect of a rapid thrombosis which may have taken place in any large vessels. In the majority of instances the simple compression of the wound, accomplished by proper application of the dressing and a firm bandage, will suffice. In injury to the large arteries of the extremities, now less frequent, a better method of procedure is to constrict the part by a rubber tourniquet, or cord tightly applied. Cases in which the direct ligation of a large main trunk is required are rare in our daily practice. The compression and constriction of a member may be continued for two or three hours without damage, and by this time it will usually be possible to apply the permanent aseptic dressing.

The emergency dressing, as a rule, consists of nothing more than a few layers of dry aseptic material, and the application of a splint for immobilizing the injured part. For the primary covering, iodoform gauze or simple sterile gauze is the

best adapted. When one of the latter articles is not available we may select some other material, but then only one that is sterile, or permissible of being made so. Finally, we have absorbent cotton to consider, an article which, unfortunately, at the present time in an emergency dressing, we too often see applied directly to the wound. This is least adapted to this purpose, as it adheres to the surface and pieces remain after removal of the dressing which retard the healing process. It is important to know that newly washed and ironed linen usually contains but a few germs, and that this is often the best substitute for sterile gauze. If we have only at hand a material the asepsis of which is questionable the circumstances may be improved by submersion of the article for ten or twenty minutes in 1 to 1000 corrosive sublimate, or better still by boiling for a few minutes, after which it is pressed out and allowed to cool.

With the various forms of injury it is impossible to lay down fixed general rules applicable through a whole course of treatment. Every case requires its particular plan, every plan its particular method of execution. One point, however, now permits definite decision and makes an important difference in the treatment to be adopted, that is as to whether we have to deal with an injury comprising a large wound, or a lesion of small proportions. The prognosis of the latter as regards the danger of infection is most favorable if we take heed of its subcutaneous character and maintain the latter state by covering the puncture with a simple dressing after the disinfection of the skin in the vicinity (see Chapter V.). To this class of injuries belong complicated fractures with small cutaneous wounds, and those in which there is moderate protrusion of the fragments, and especially the gunshot injuries produced by our modern small-calibre weapons. Von Volkmann announced before the German Conference of Surgeons in

1871 and 1872, as a result of his experience in the war of 1866 and 1870, that these injuries run the most favorable course when we refrain from all radical surgical procedures—incision, drainage, etc.; simply apply an occlusive dressing and treat the wound as subcutaneous. It was with this principle of the aseptic occlusive dressing that v. Bergmann and his assistant Reyher obtained such brilliant results in the Russia-Turkish war. We must admit that, in the case of a compound fracture, pathogenic organisms may gain entrance to the wound along the protruding spicula of bone even though the spicula be removed, and that in gunshot injuries the same may occur through the medium of the bullet. But it is a fact that under the occlusive dressing an unfavorable result has seldom been seen. Almost invariably these injuries run a course unattended by reaction, in case of the gunshot wound the missile becoming quietly encapsulated. In the hospital of a city with a population of a million, gunshot injuries and compound fractures are by no means rare, and still in the von Bergmann Clinic we cannot recall an instance in which a simple gunshot wound or fracture with small external opening has not healed properly under the aseptic occlusive dressing. In the battle of Gorni Dubnik of the Russia-Turkish war, von Bergmann selected from a number of cases of gunshot injury to the knee, fifteen of the most serious in which, aside from the opening of the knee-joint, there was extensive comminution of bone. These cases were treated with the aseptic occlusive dressing, after a disinfection of the skin in the region of the wound, salicylic gauze being applied and the limb immobilized in plaster of Paris, and with but a single exception perfect recovery took place, notwithstanding the fact that the patients were exposed for days to pouring rain and had to be transported across the plains over muddy roads. It is these injuries of the knee-joint which in military practice previously gave the most grave results, and

in which Reyher, with use of exploration, at that time still much in vogue, and without any aseptic dressing, had a mortality of over nintey-five per cent.

In extensive wounds of the soft parts, the surgeon, guided by his experience, must provide the most favorable conditions, being influenced also by the character of the injury. At the present time good results are obtained in these cases by the very free use of the iodoform gauze tampon. Limbs are thus saved which even at the beginning of the antiseptic era would have been surrendered to the amputating knife. The wounds with extensive contusion frequently associated, and detachment of the skin over a large area, are prepared for dressing according to the principles enunciated in the preceding chapter for large operation wounds. The irrigation with sublimate and carbolic acid solution, so much employed in the past time, is also to be avoided within reasonable limits, and a sponging and absorption of the blood with sterile gauze substituted.

The surgeon must make it an absolute rule to operate only when he has at his disposal the means essential to asepsis. With propriety war sanitary regulations restricted the primary field dressing to a simple covering of the wound and immobilization of the injured part. All further attention devolved upon the hospital or lazaretto authorities. The physician summoned to attend a person who is injured has, as his chief duty, to withhold all unnecessary and injurious manipulations, simply apply an emergency dressing and send the patient to the nearest hospital. In the vast majority of instances this is all that will be necessary. Exceptionally operation may be required under the primitive conditions, but just these exceptional cases in the hands of skilled surgeons afford asepsis the opportunity of demonstrating its greatest efficiency and achieving its most brilliant triumphs. Where fire, water, and a kettle are obtain-

able, the surgeon possessed of ingenuity and familiar with the rules of asepsis is enabled to improvise. In the boiling water in which the instruments are sterilized, sutures and ligatures are asepticized and moist dressing material provided, by the submersion of pieces of linen for a long time and then compressing them. The surgeon removed from civilization can perform emergency amputations, ligate main vessels, or operate for the relief of strangulated hernia and have his results correspond with those of one who performs his work in the marble-paved arena.

In private practice the portable dressing-case of Dr. Roswell Park will be found of value. The latter consists of one of the old-style Schaffhausen metal emergency cases, made for military surgeons. Inside of this are dishes composed of copper, which fit snugly into it. On removal they serve as basins, trays, etc. Into the trays can be packed any form of aseptic dressing material which best suits the surgeon, sterilized gauze in packages, sponges, or whatever he may need. The gauze which Dr. Park uses is sterilized in an ordinary fruit jar, in the bottom of which is placed a drachm of naphthalin or of iodoform. The cover is then closed loosely and the jar put into the steam sterilizer or it can be placed in a kitchen oven, in boiling water, or in a steam boiler, and subjected to heat for a length of time varying with the degree of heat,—if it be that of boiling water, for about half an hour. By the heat the antiseptic is volatilized, and its vapor, permeating the loose gauze, impregnates it everywhere with its own substance. On removal from the steam sterilizer, the jar is hermetically sealed, and can then be carried in any desired shape.

The catgut employed is wound upon pieces of glass tubing, three or four feet on each piece, after having been deoleated by soaking for a day or two in benzine or ether, and sterilized by boiling in alcohol under pressure. The pieces of tubing

are kept in a large receiver filled with alcohol. As needed a few are transferred to a small bottle of alcohol and placed in the portable dressing case. Each tube contains but a small quantity of catgut, and once removed they are not returned to the receiver, the portion of ligature not used being thrown away.

For disinfection of the hands and of the patient's skin, Dr. Park now resorts, for the most part, even in his hospital practice, to mustard, which he considers by all means the most reliable of easily accessible antiseptic materials. He suggests to carry in the operating case a small jar of green soap, with which the hands and arms are carefully washed and scrubbed. During the use of this, a half-teaspoonful, or more, of common powdered mustard is thoroughly rubbed into the hands, or the washing with mustard may be made a separate affair. This method has been subjected to crucial tests, and more confidence is placed in it than in any other material, both as a deodorizer and as an antiseptic, while of all the reliable methods this is that which leaves the least disagreeable sensation about the parts. In the same way that region of the patient's body which is to be operated is scrubbed with this combination, while after shaving the parts fine mustard is again rubbed in, and then carefully washed off.

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CHAPTER XVI. Aseptic Emergency Dressings and the Care of the Wounded—Improvision.

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